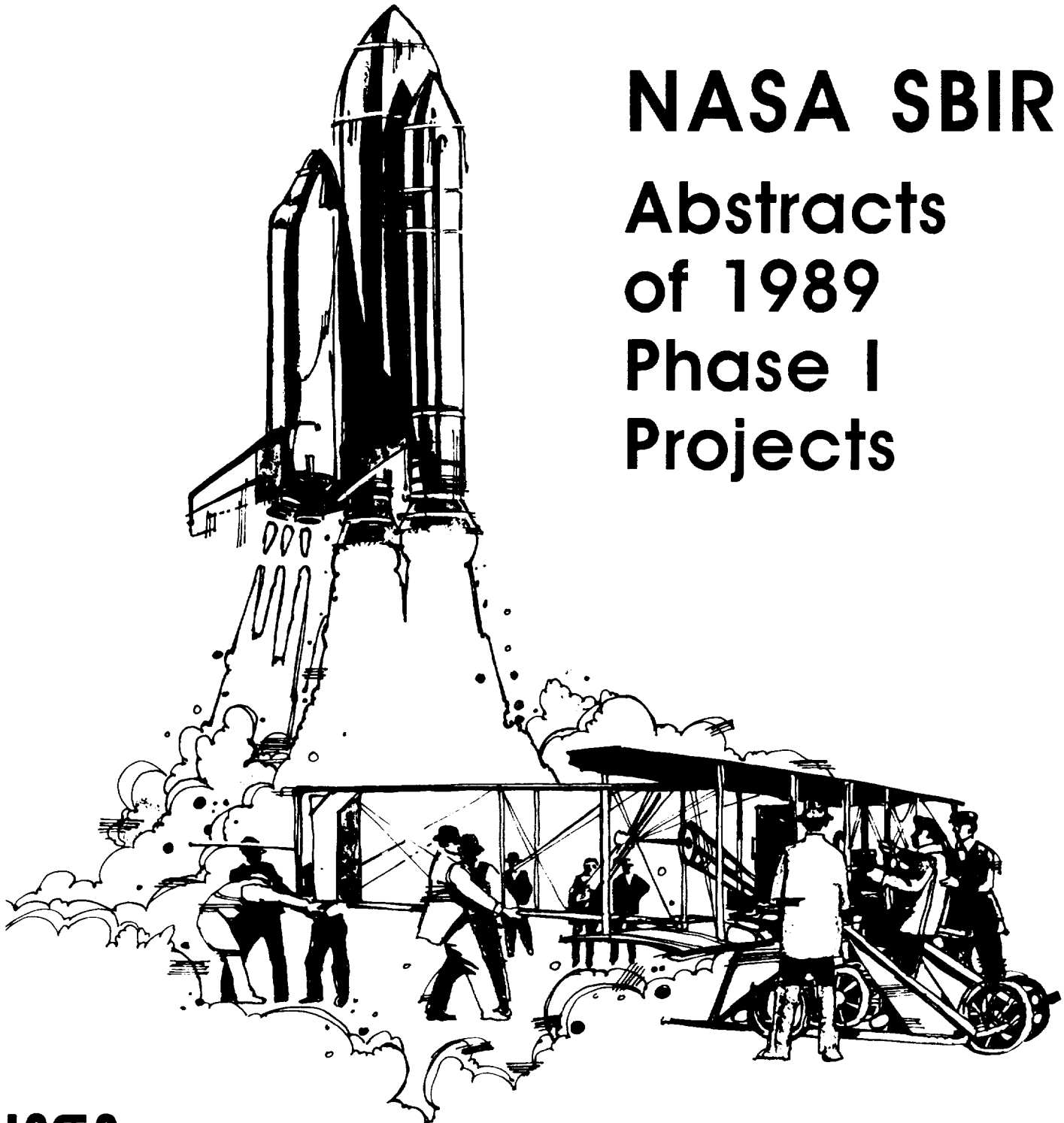
NASA SBIR

Abstracts of 1989 Phase I Projects



NASA
National Aeronautics and Space Administration

Small Business Innovation Research Program
Washington, DC 20546

Prepared for the Small Business Innovation Research Office, Office of Commercial Programs, National Aeronautics and Space Administration, by F. C. Schwenk, J. A. Gilman, and J. B. Paige of FUTRON, Inc., Bethesda, MD.

Introduction

Objective

The objective of *Abstracts of 1989 Phase I Projects* is to provide information about the Small Business Innovation Research (SBIR) program to anyone concerned with National Aeronautics and Space Administration (NASA) R&D activities. The information in the abstracts was supplied by the participating small businesses and has been issued by NASA solely for the purpose of information exchange. NASA does not guarantee its accuracy or validity. Readers are encouraged to contact the small businesses for further information or clarification.

Contents

This document is one of a series documenting the results of Small Business Innovation Research projects supported by NASA. It contains edited, non-proprietary proposal abstracts of the set of Phase I projects initiated as part of the 1989 Program Year. Activities associated with a Program Year encompass all Phase I projects which result from an annual Program Solicitation and the Phase II projects subsequently selected for continuation. The appendixes provide background information on the SBIR program, the technical topic and subtopic areas in which proposals were solicited in 1989, and five indexes. These contain listings through which project descriptions may be cross-referenced by their locations by state, by company, by principal investigator, by NASA Field Center responsible for management of each project, and by contract number. For simplicity, each project has been assigned a sequential identifying number, from 001 to 249, in ascending order as found in the body of the report.

The 1989 Phase I Projects

The closing date for the 1989 SBIR Program Solicitation was June 28, 1989, at which time NASA had received 2142 Phase I proposals. Following the evaluation and selection process, NASA negotiated and awarded Phase I contracts for 249 projects. These contracts were placed with 201 different small R&D firms located in 35 states. In December 1990 and February 1991, a total of 121 of these projects were selected for negotiation of Phase II contracts; the abstracts of these projects are marked with an asterisk.

Program Management

Program management is provided by the SBIR Program Office in the NASA Headquarters Office of Commercial Programs. The proposals are evaluated by nine NASA Field Installations that also let the contracts and manage individual projects. Each project description includes the abbreviation of the managing Center.

- **ARC** Ames Research Center, Moffett Field, CA 94035
- **GSFC** Goddard Space Flight Center, Greenbelt, MD 20771
- **JPL** Jet Propulsion Laboratory, Pasadena, CA 91109
- **JSC** Johnson Space Center, Houston, TX 77058
- **KSC** Kennedy Space Center, FL 32899
- **LaRC** Langley Research Center, Hampton, VA 23665
- **LeRC** Lewis Research Center, Cleveland, OH 44135
- **MSFC** Marshall Space Flight Center, AL 35812
- **SSC** Stennis Space Center, MS 39529

Technical Topics

The order of abstract presentation is according to technical topics. Since 1984, each NASA SBIR Program Solicitation has contained the following fifteen technical topics:

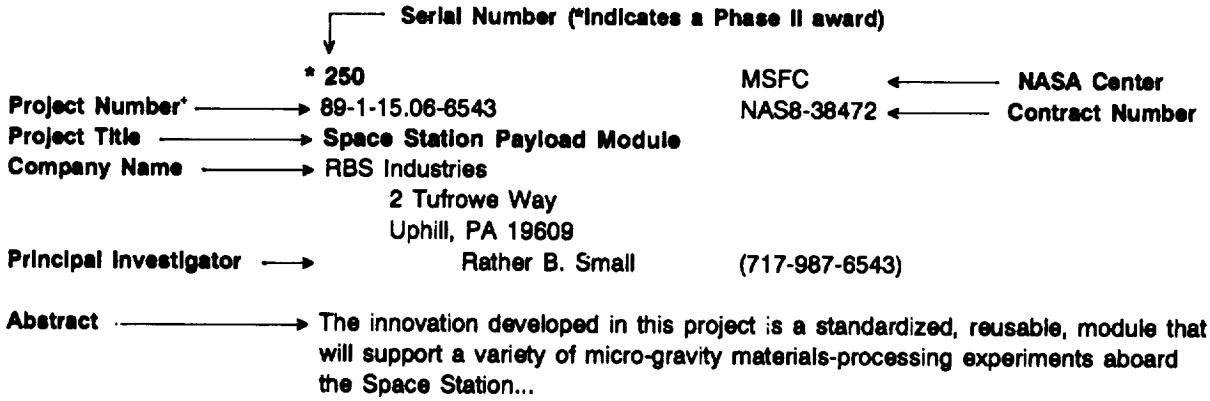
01	Aeronautical Propulsion and Power
02	Aerodynamics and Acoustics
03	Aircraft Systems, Subsystems, and Operations
04	Materials and Structures
05	Teleoperators and Robotics
06	Computer Sciences and Applications
07	Information Systems and Data Handling
08	Instrumentation and Sensors
09	Spacecraft Systems and Subsystems
10	Space Power
11	Space Propulsion
12	Human Habitability and Biology in Space
13	Quality Assurance, Safety, and Check-out for Ground and Space Operations
14	Satellite and Space Systems Communications
15	Materials Processing, Microgravity, and Commercial Applications in Space.

Subtopics

Each technical topic contains a number of subtopics that specify the problems or opportunities to which small firms are invited to address Phase I proposals. The number and content of the subtopics change from year to year, depending on the interests of the agency. The SBIR Program Solicitation for 1989 included the 150 subtopics listed in Appendix B.

Project Information

Each project description begins with the serial number and the project number. The project number is composed of the program year (89), the topic and subtopic numbers (15.06), and an identifying number (6543). The data is the most current available. In cases where firms have changed names or rights to Phase I results have been sold, the new name or owner is shown.



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NASA

Small Business Innovation Research

Abstracts of 1989 Phase I Projects

01: Aeronautical Propulsion and Power

* 001 LeRC
89-1-01.01-0333B NAS3-25835
Flow in Turbine Blade Passages
Scientific Research Associates, Inc.
P.O. Box 1058
Glastonbury, CT 06033
Brian E. Thompson (203-659-0333)

Knowledge of the detailed flow structure in internal passages of gas turbine blades is needed to understand measured heat transfer phenomena and to validate computational analysis and design methods. The objectives of this project are to obtain measurements, validate computational techniques, assess cooling strategies, and contribute to design practices all relevant to turbine-blade passages. Recently developed, refractive-index-matching techniques will be used to obtain detailed measurements of mean and fluctuating velocity components in rotating passages with geometries and conditions representative of those found in gas-turbines. In Phase I, a refractive-index-matching experiment will be compared to heat transfer results previously obtained in a simplified but relevant rotating passage configuration. In Phase II, this experiment would be extended to more complex geometries closer to those of turbine-blade passages. Results would be obtained to provide bench-mark data for Phase II code validation. These experimental and computational techniques would be also applied in Phase II to assess cooling strategies in preparation for integration into turbine-blade design systems.

Potential Commercial Applications: Improved turbine-blade configurations that allow higher turbine inlet temperatures with performance and design advantages would be of great interest to commercial gas-turbine engine manufacturers.

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* 002 LeRC
89-1-01.01-1732A NAS3-25880
Grid-Generation Code with Automatic Zoning
Program Development Corp. of Scarsdale
300 Hamilton Avenue, Suite 409
White Plains, NY 10601
Peter R. Eiseman (914-761-1732)

The grid generation code TURBO is a menu-driven code that operates interactively to produce single-block grids for numerical flow-field simulations of turbomachinery problems. To gain a substantive advantage, a zoning scheme will be developed for TURBO so that it can readily be applied in a multi-block environment. For a given grid topology, the zoning would be accomplished in an automatic manner once certain defining parameters are inserted. Upon accomplishment, the capability will be established for a user to select a grid topology from a menu and then proceed quickly from a good global start to exercise the local grid-manipulation controls in TURBO.

Potential Commercial Applications: A greatly enhanced TURBO code should have a ready market among the scientists and engineers who need to study turbomachinery flow fields.

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003 LeRC
89-1-01.01-9030A NAS3-25839
Reaction Mechanics and Kinetic Rates for Soot Formation
Physical Sciences, Inc.
20 New England Business Center
Andover, MA 01810
W. Terry Rawlins (508-689-0003)

The design of advanced gas turbine engines needs predictive models of soot formation and radiation in the high-pressure combustion of future, practical hydrocarbon fuels. The development of such models requires a fundamental data base, in the appropriate pressure regimes for elucidating the mechanisms governing polycyclic molecular growth, oxidative inhibition of sooting, and soot-particle nucleation and growth. Advanced optical shock tube techniques will be used to provide a data base against which to test modeling concepts.

Potential Commercial Applications: This work would support design of advanced gas turbine and diesel engines for use in both the public and private sectors.

***

*** 004** LeRC
89-1-01.02-5086 NAS3-25873
Evaluation of PS200 Coating as a Thermal Barrier in an Air-Cooled Rotary Engine
Moller International, Inc.
1222 Research Park Drive
Davis, CA 95616
Mike Griffith (916-756-5086)

Thermal-barrier coating applied to housings of rotary engines reduce engine heat rejection, improve thermal efficiency and reduce cooling requirements. However, recent tests indicate that a thermal-barrier coating on the side housing of an air-cooled rotary engine results in surface temperatures beyond the capability of conventional hydrocarbon lubricants. This project will investigate the application of the PS200 coating over the thermal-barrier coating in order to provide high-temperature lubricity. The PS200 plasma-applied coating, developed at the NASA Lewis Research Center as an unlubricated wear coating for Stirling engines, consists of chromium carbide with silver and a fluoride eutectic for high temperature lubricity. Applied over a thermal barrier coating, it may permit engine operation without external lubrication. The coating evaluation on a side housing could lead to the insulation of the entire combustion chamber of the rotary engine by coating the rotor housing with the same thermal-barrier and PS200 coating combination.

Potential Commercial Applications: This technology could be applicable to any low-heat-rejection engine (piston or rotary, liquid or air-cooled) including the stratified-charge, multi-fuel rotary engine in development for several military and commercial applications.

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005 LeRC
89-1-01.02-6576 NAS3-25834
Rapid-Mix Concepts for Low-Emission Combustors in Gas Turbine Engines
CFD Research Corporation
3325-D Triana Boulevard
Huntsville, AL 35805
Clifford E. Smith (205-536-6576)

Innovative rapid-mix concepts will be studied for rich-burn, quick-quench, and lean-burn (RQL) gas turbine combustors applicable to future high-speed aircraft. Conventional quick quench sections for circular flame tube configurations have employed radial in-flow holes or slots, and little mixing optimization has been performed. Two concepts are proposed for improved mixing: asymmetric jet penetration (AJP) and a lobe mixer (LM). In Phase I, the AJP concept will be studied. Two schemes of the AJP concept will be analyzed: a counter-vortex scheme and a co-vortex scheme. These schemes produce multiple vortex patterns which are substantially different from the conventional concepts and have the potential of enhancing overall mixing. Three-dimensional computational fluid dynamics (CFD) techniques will be employed to analyze and compare the proposed AJP schemes with a conventional rapid-mix concept. In Phase II, the same CFD methods would be employed to screen the LM concept. The most promising AJP or LM concept would be selected, optimized, and experimentally tested to show its potential of minimizing NO_x formation.

Potential Commercial Applications: The final optimized and tested RQL combustor design can be patented and commercialized to gas turbine engine manufacturers.

***

006 LeRC
89-1-01.02-9888 NAS3-25955
Influence of Tooth-Profile Modification on the Lubrication of Involute Gearing
Management Project Marketing Consultants
5902 East Hadrians Court
Anaheim, CA 92807-3919
Lotfi E. El-Bayoumy (714-637-8910)

A transient thermal analysis approach will be utilized in evaluating the effect of profile modification on the bulk temperature of involute gears. Linear, parabolic, and circular-arc modifications will be considered. A finite-element generation program, designed for use in gear cooling analysis, will be modified to incorporate profile modification capability. A recently developed, thermal model will be used in assessing the impact of these profile modifications. An optimization process is planned to develop design charts in terms of amplitude and normalized length of the modified portion so as to minimize the temperature rise over the gear tooth. The results of this project should be of significant value in designing high speed gearing where scoring is a primary mode of failure.

Potential Commercial Applications: Commercial applications would be in improved gear manufacturing methodology, improvement of the gear scoring index, and enhanced gear transmission reliability

***

007 LeRC
89-1-01.03-4888 NAS3-25826
High-Temperature, Hostile-Environment Instruments Manufactured by CVD
Delta G Corporation
9960-A Glenoaks Boulevard
Sun Valley, CA 91352
Robert A. Holzl (818-767-4888)

This project takes advantage of the development, made in the mid-1960s for the U.S. Atomic Energy Commission, of a temperature-measuring device for the nuclear rocket reactor. It was successfully tested at temperatures over 2200°C. This project will reproduce the device with modifications to make it useful in a high-temperature oxidizing and erosive environment. The design includes a tungsten and tungsten 25-rhenium, co-axial thermocouple made entirely by the chemical vapor deposition (CVD) process. The miniaturization made possible by the use of CVD allows for minimal intrusion of the probe into a working fluid. The high-temperature strength suggests good longevity for the device. A working model will be constructed and tested at 1900°C in air. Other possible uses for CVD

processing for instrument devices for hostile environments will also be studied.

Potential Commercial Applications: Commercial applications include gas temperature measurements in gas turbine engines, rocket nozzles, and natural gas furnaces.

***

*** 008** LeRC
89-1-01.03-9030 NAS3-25840
Laser-Induced Fluorescence Measurements of Velocity in Supersonic Reacting Flowfields
Physical Sciences, Inc.
20 New England Business Center
Andover, MA 01810
Mark G. Allen (508-689-0003)

This project's approach to non-intrusive velocity measurements in reacting flow fields is based on the Doppler-shifted fluorescence of the OH radical. It addresses a critical need in the area of non-intrusive combustion diagnostic measurements and finds particular application in the design of supersonic ramjet propulsion systems. The innovation is based on the Doppler-shift of a moving ensemble of molecules relative to a stationary ensemble. By recording the relative fluorescence profiles of stationary and moving groups of molecules, the mean velocity component aligned with the laser beam may be determined. In reacting flows, the radical OH will be distributed over a large portion of the flow field and is proposed as the fluorescence tracer species. In flows without chemical reactions, possible tracers include NO seeded into the flow or O_2. This approach circumvents inherent limitations in laser Doppler anemometry and hot-wire techniques. Preliminary signal estimates with OH show good sensitivity for velocities as low as 3×10^4 cm/s.

Potential Commercial Applications: The proposed technique will find extensive application throughout the aerospace industry and other industries developing air-breathing propulsion systems.

***

009 LeRC
89-1-01.03-9654A NAS3-25828
Non-Intrusive, Single-Point Pressure and Temperature Sensor for Aeronautical Propulsion Applications
Teknowlogica, Inc.
P.O. Box 145
Princeton Junction, NJ 08550
Robert W. McCullough (609-799-9654)

A non-intrusive instrument to measure pressure and temperature at a point in flows containing oxygen is being investigated. It would use an ultraviolet source to induce fluorescence in oxygen. The intensity and spectral content of the fluorescent signal in combination with the Rayleigh signal would be used to infer pressure and temperature at a point in the flow field. The concept differs from laser-induced fluorescence (LIF) in the use of a low-cost pump source and the examination of broad spectral regions. Phase I research uses existing spectral models to explore design concepts, to perform simple lab experiments using available equipment to validate models, and to develop a preliminary conceptual design of a prototype instrument. Phase II efforts would consist of detailed design, fabrication, and testing of the prototype instrument. Due to the physical mechanism involved, it is expected to be applicable for pressures ranging from 0.1 atm to 10 atm and temperatures from 200K to 1500K. This range of operation would make it valuable for supporting the development of aeronautical propulsion systems.

Potential Commercial Applications: Remote measurement of temperature and pressure fields inside wind tunnels and propulsion systems would be the primary application.

***

010 LeRC
89-1-01.04-2685 NAS3-25941
High-Efficiency Flow Induction
Foa Engineering
11319 Commonwealth Drive, #101
North Bethesda, MD 20852
Joseph V. Foa (301-467-3926)

This project investigates a method for improving the energy transfer efficiency of "direct-flow induction" processes through enhancement of the single non-dissipative component that is the work of interface pressure forces. This is achieved by imparting a transverse motion to paddle-like jets of the energizing fluid without, however, imparting the same motion to the fluid particles that make up the jets themselves and, hence, at no energy cost except for frictional losses. The transfer of momentum and energy from these "fluid paddles" to the flow to be induced will take place in good part through the work of the pressure forces that the two flows exert on one another at their moving interfaces. Use of this mechanism can be expected to lead to the development of improved jet pumps and thrust- or lift-augmenting ejectors.

Potential Commercial Applications: Applications would occur in thrust or lift augmenters for airliners and general aviation, improved water jet thrusters for marine propulsion, improved ejector pumps, and fuel injectors for scramjets.

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02: Aerodynamics and Acoustics

011 ARC
89-1-02.01-1427 NAS2-13176
Two-Equation Turbulence Modeling of Hypersonic Transitional Flows with the UPS Code
Applied and Theoretical Mechanics, Inc.
4501 Sequoyah Road
Oakland, CA 94605
Joelle M. Champney (415-635-1427)

The project seeks to improve the ability of turbulence models to solve transition and turbulence phenomena in the hypersonic regime. The state-of-the-art UPS computer code, developed at NASA Ames Research Center, will be the basic numerical tool. Two-equation turbulence models, upgraded by a transition model, will be incorporated into the UPS code in a "loosely" coupled manner. The transition model, based upon the production term modification (PTM) developed by Schmidt and Patankar for low speed flows, will be extended to hypersonic flows. The transition model will determine onset and end of transition; no such hypersonic transitional model exists at the present time. The PTM technique includes two constants that will be adjusted using empirical correlations for onset and end of transition for hypersonic flows over cones. The model will be tested by predicting transition processes and comparing them with transition experiments for hypersonic flows over cones at Mach numbers of 6 and 8.

Potential Commercial Applications: This work will provide a numerical tool to predict the important transitional processes on hypersonic aircraft and will improve the numerical design process presently used by industry.

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012 MSFC
89-1-02.01-3304 NAS8-38471
Coupling Grid Adaption to an Implicit Navier-Stokes Solution Procedure
Amtec Engineering, Inc.
3055 112th Avenue NE #208
Bellevue, WA 98004
Scott T. Imlay (206-827-3304)

A grid-adaption procedure will be investigated for a recently developed class of Navier-Stokes solvers which use relaxation rather than approximate factorization to solve the linear system of equations. The objective is the implicit coupling of an existing two-dimensional Navier-Stokes code and an existing two-dimensional grid-adaption code. The grid-adaption code uses a spring and damper analogy and a novel non-linear spring to avoid grid-depletion problems. During the Phase I, the grid-adaption procedure will be refined to control grid orthogonality and improve convergence, and methods of implicitly coupling grid-adaption to the Navier-Stokes solver will be investigated. The combined adaptive-grid, Navier-Stokes solution procedure will then be tested on representative supersonic and transonic flow problems.

Potential Commercial Applications: Commercial and federal government applications may occur in the analysis of viscous flow fields for a wide range of flight vehicles and components.

***

*** 013** LaRC
89-1-02.01-3800 NAS1-19024
Advanced Modeling of Combustion Systems
creare.x Inc.
Box A-219
Hanover, NH 03755
Jayathi Y. Murthy (603-643-2600)

The accurate prediction of flow, species concentration, and temperature is essential to the characterization and design optimization of combustors. To this end, it is essential to include the effects of non-gray radiation and finite-rate chemical kinetics in combustion modelling. This project addresses novel and highly parallel techniques for this purpose. The discrete transfer model is used for non-gray radiation. For stiff kinetics, a point-wise solution technique using stiff solvers for ordinary differential equations is utilized. The Phase I effort will evaluate these techniques within the framework of the firm's commercial code FLUENT; verification problems from the literature will serve to establish the correctness of results obtained. Phase II would extend the implementation to non-orthogonal grids in our code FLUENT/BFC. At culmination, this work would provide a comprehensive tool for the modelling of turbulent, reacting subsonic flow and heat transfer in complex combustor geometries.

Potential Commercial Applications: Enhanced capabilities for the firm's current code, FLUENT, which is presently being applied by industrial clients to model combustion applications, will find reception in the gas turbine and the chemical vapor deposition communities.

***

014 LaRC
89-1-02.02-0559 NAS1-19031
Wind Tunnel Noise Reduction
Atlantic Applied Research Corp.
4 A Street
Burlington, MA 01803
John F. Wilby (617-273-2400)

Sound and turbulence generated by the interaction between the flow and structures in wind tunnels adds to the fan noise and establishes the lower limit of background noise. It interferes with the measurement of acoustic radiation from test articles and the performance of transition experiments. Rather than attenuating sound after it has been generated, this project addresses the reduction of flow-structure noise at the source by modification of structures such as turning vanes, struts, and nozzle lips. The concept involves the use of porous, perforated, or serrated edges to provide a gradual hydrodynamic and acoustic transition at the edge so that the flow experiences a gradual change of boundary conditions from a solid body to free air rather than a discontinuous change at a

leading or trailing edge. Experiments on three types of trailing edges will be performed in the firm's quiet wind tunnel to validate the analytical relations and to establish scaling relations. Results will be applicable to the retrofit of existing facilities and to the design of new acoustic research tunnels.

Potential Commercial Applications: Results will have application to many government, aerospace, and automobile industry wind tunnels. Quiet wind tunnels are planned in all these areas.

***

015 LaRC
89-1-02.03-5750 NAS1-19017
Transition to Turbulence in Complex Aerodynamic Flows
Nektonics, Inc.
875 Main Street
Cambridge, MA 02139
Edward T. Bullister (617-868-0101)

The goal is of this project is to develop a user-friendly CFD tool based on the spectral-element, general geometry computer code, NEKTON, to compute the transition to turbulence in complex geometry flows. The spectral-element, flow solvers in NEKTON offer the advantage of accuracy, efficiency, and robustness in comparison with other numerical methods. This code will be enhanced through the introduction of a renormalization-group-based subgrid model to allow the code to calculate from laminar flow to developed turbulence. Phase I will study prototypical, complex geometry flows, will explore the supercritical versus subcritical character of shear-flow transition in complex geometry, and will test the RNG sub-grid model. Phase II would extend NEKTON into a general-purpose, transition-simulation tool for engineering through improved meshing schemes, improved subgrid models, and general purpose interfaces to workstations.

Potential Commercial Applications: The enhanced NEKTON transition analyzer should reduce design costs and improve design reliability for airframe manufacturers, process and manufacturing industries, and users of any industrial process in which flow stability is important.

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*** 016** MSFC
89-1-02.03-9391 NAS8-38466
Calculation of Surface Pressure Fluctuations Based on Time-Averaged, Turbulent Flow Computations
Engineering Analysis, Inc.
715 Arcadia Circle
Huntsville, AL 35801-5909
Frank B. Tatom (205-533-9391)

The structural dynamic analysis of a space vehicle during atmospheric flight requires knowledge of the mean and fluctuating pressure distribution over the surface of the vehicle. Computational fluid dynamic techniques can readily calculate the mean pressure component but not the fluctuating component. Experience with the turbulence analysis (TURBAN) software model will be applied to develop an accurate and efficient method to predict the intensity of surface-pressure fluctuations based on the properties of the mean flow field as computed by standard CFD procedures. Specific objectives for Phase I are: to establish the basic governing equation for the covariance of pressure fluctuations; to determine the most practical numerical procedure; to develop computational algorithms; to select candidate two-dimensional incompressible flow problems which have CFD solutions; and to predict distribution of surface pressure fluctuations. During Phase II, the technique would be expanded to apply, first, to three-dimensional incompressible flow and, then, to two-dimensional and three-dimensional compressible flow. In its final stage of development, the concept would take the form of a CFD post-processor which could be used in conjunction with a variety of CFD software programs.

Potential Commercial Applications: Commercial applications would be through the sale of the software as a post-processor to companies developing and utilizing CFD software.

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017 ARC
89-1-02.04-0688A NAS2-13171
A Holographic Interferometer Spectrometer for Hypersonic Flow
Metrolaser
18006 Skypark Circle #108
Irvine, CA 92714-6428
James D. Trolinger (714-553-0688)

Holographic interferometry, widely used for diagnosis of flow fields, provides an instantaneous, three-dimensional density distribution by observation of the fringe variations of an interferogram. When optical path-length changes exceed one wavelength of light, the flow field can be easily observed. When optical path-length changes are much less than a wavelength of light, the problem is complicated since fringe shifts are barely visible. A problem of current critical interest in aerodynamics is the diagnosis of hypersonic flows involving low densities, short path-lengths, and the mixing of flows. As a result, improved sensitivity and the ability to distinguish constituents are needed. This project combines unique and innovative concepts with state-of-the-art hardware to improve sensitivity and information content by orders of magnitude over current systems. Specifically, the innovations include recording the Fourier transform at resonance with tunable or multiple wavelength lasers and reconstructing with a new phase shifting technique.

Potential Commercial Applications: This system will have applications in industries requiring flow diagnoses in hypersonic wind tunnels, combustion facilities, and other types of test facilities.

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* **018** ARC
89-1-02.04-1520 NAS2-13172
Remote Measurement System for Arc-Jet Temperature and Density
Deacon Research
2440 Embarcadero Way #B
Palo Alto, CA 94303
Douglas Bamford (415-493-6100)

The properties of arc-jets used in laboratory simulation of the shock-created plasmas experienced during atmospheric re-entry must be known in order to assess direct spacecraft heating and hot-gas transport to the rear of the vehicle. We will investigate the use of laser-induced fluorescence to obtain detailed information about arc-jet properties. One advantage of this technique is direct measurement of the absolute number densities and translational temperatures of oxygen and nitrogen atoms, which should improve predictions of spacecraft heating by surface recombination. Another advantage is direct measurement of vibrational and rotational temperatures for minor components of the flow, which should serve as "thermometers" for the overall energy distribution within the flow. The LIF technique is sensitive, is flexible enough to be used on many different species, and can make multiple species measurements (or temperature measurements on a single species) instantaneously. After choosing the optimum LIF scheme, we will design a prototype, laser-based detection system. This system would be constructed and calibrated in a Phase II effort and, eventually, installed and operated on an appropriate NASA arc-jet facility.

Potential Commercial Applications: The applications would be in the design of advanced space vehicles and aircraft such as the National Aerospace Plane.

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019 LaRC
89-1-02.04-4007 NAS1-19018
Transport Properties in Non-Equilibrium Air Mixtures
Hansen Research Associates
P.O. Box 30133
Eugene, OR 97403
C. Frederick Hansen (503-344-4007)

The first purpose of this project are to determine how closely simple, weighted, cross sections can match the collision integrals of the Chapman-Cowling formulation as a function of temperature. The second is to demonstrate that simple formulae for viscosity, thermal conductivity, and mass diffusion of gas mixtures approximate the functional form of more exact models. The third purpose is to find empirical adjustments of the cross sections and/or constant coefficients in the mixture formulae which will not only retain the proper functional form but will also quantitatively reproduce more exact models. The goal is to provide a fast, efficient algorithm which can be used in CFD programs with the most speed possible so that these programs can find solutions to complex, non-equilibrium airflow conditions in reasonable computation times. The methods developed will also provide a basis for quick calculation of transport properties of gas mixtures other than air.

Potential Commercial Applications: The methods developed would apply to all high temperature gas systems such as combustors, turbines, internal combustion engines, etc., whether for commercial or government applications.

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* **020** JSC
89-1-02.04-9030 NAS9-18326
High-Velocity Gas-Surface Accommodation
Physical Sciences, Inc.
20 New England Business Center
Andover, MA 01810
George E. Caledonia (508-689-0003)

A knowledge of the velocity-dependent, gas-surface accommodation behavior of ambient species impacting high-performance aerospace materials is critical for the proper design of hypersonic vehicles which operate in rarefied atmospheres. To investigate surface-energy and momentum accommodation of high-velocity gases on selected materials, we will employ a unique beam source which can provide high fluxes of oxygen atoms and mixtures of N and N_2 at hypersonic velocities of interest, 4 to 12 kilometers per second. The resulting data base would find direct application for performance predictions for flight vehicles such as AFE and NASP.

Potential Commercial Applications: A unique test facility for the characterization of the accommodation and surface-catalytic properties of high performance aerospace materials could be used in hypersonic rarefied-flow applications in both terrestrial and planetary atmospheres.

***

021 LaRC
89-1-02.04-9457 NAS1-19027
A Model for Shock Turbulence Interaction
Nielsen Engineering & Research, Inc.
510 Clyde Avenue
Mountain View, CA 94043-2287
Robert E. Childs (415-968-9457)

One of the most important issues in developing computational fluid dynamics methods for hypersonic flow is turbulence modeling. One of the unique aspects of hypersonic flow is the substantial effect of the shock waves on turbulence. Previous work has found that current turbulence models do not represent the interaction of the shock motion with the turbulence and that this interaction is considerable. This project is concerned with developing a turbulence model to account for this phenomenon.

Potential Commercial Applications: This model will be useful to the aerospace industry and will enhance the company's range of commercially available software.

***

022 MSFC
89-1-02.05-8581 NAS8-38456
Coupling of Unsteady Fluid Dynamics and Structures in Low-Density, High-Speed Flows
Remtech, Inc.
3304 Westmill Drive
Huntsville, AL 35805
Sarat C. Praharaj (205-536-8581)

NASA has been reviewing lightweight, umbrella-type, elastic aerobraking orbital-transfer vehicles to operate at the hypersonic Mach numbers in the low-density region of the atmosphere. The payloads that are mounted in the wake region of the aerobrake will be subject to time-varying aerodynamic loads due to impingement of the non-steady shear layer separating from the aerobrake. Cyclic variations in the aerodynamics and aeroheating of the aerobrake and shear layer impingement on the payload may cause structural failure. A computational technique is required to couple a compressible, time-accurate CFD code with a structural analysis code to simulate fluids-structures interactions. Some investigations have been made for fluids-structures coupling in transonic flow, but almost no significant developments exist for the low-density, hypersonic flow regime. This project will conduct a literature survey of compressible time-dependent flow, choose a suitable structural response code, and develop a coupling procedure including a moving grid algorithm and time-step calculation procedure.

Potential Commercial Applications: This code will be applicable to any high-altitude ascent or re-entry vehicle.

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*** 023** ARC
89-1-02.06-8228A NAS2-13155
Aerodynamic Control of the F/A-18 Using Forebody Vortex Blowing
Eidetics International, Inc.
3415 Lomita Boulevard
Torrance, CA 90505
Gerald N. Malcolm (213-326-8228)

Improved agility and maneuverability for future fighter aircraft by use of aerodynamic control at high angles-of-attack has been demonstrated through forebody vortex manipulation. This project applies the generic technology to a forebody blowing scheme that could be flight tested by the NASA F-18 HARV. The Phase I effort will determine the most effective placement and orientation of blowing nozzles or slots on an F-18 model to create the largest effect on the forebody vortex structure with the minimum blowing rate. Water tunnel flow experiments in the firm's 24x36-inch water tunnel will be used in visualizing the vortex structure with various blowing schemes over an angle-of-attack range to at least 60°. Results will guide planning for wind tunnel force and moment tests of sub-scale models in Phase II and for possible tests of a full-scale F-18 in the NASA Ames 40x80x120-foot wind tunnel. Successful development of a forebody blowing system in Phase II could lead to full-scale flight tests on the F-18 HARV.

Potential Commercial Applications: Forebody vortex control could become a viable option for the design of aerodynamic control systems of future aerospace vehicles.

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024 ARC
89-1-02.07-3017A NAS2-13157
Soft Hub for Bearingless Rotors
Advanced Technologies, Inc.
812 Middle Ground Blvd
Newport News, VA 23606
Peter G. Dixon (804-873-3017)

The rotary wing industry has striven to develop a bearingless main rotor (BMR) having no mechanical bearings. All true BMR systems are limited by the strength in static-fatigue loads versus flapwise flexibility, resulting in limited G-maneuvers from a highly responsive rotor system. The soft-hub rotor concept explored in this project allows tilting of the rotor by a disc moving the virtual hinge inboard, eliminating this undesirable limitation. It provides the simplicity of a true bearingless main rotor system with flapping angles up to plus-or-minus 15 degrees and allows the BMR to be used on all rotor-craft configurations, even tandem rotors. The objective is to develop a feasible soft-hub design based on the use of existing composite materials. Various levels of "soft hub" stiffness will be analyzed to obtain a match of mission and rotorcraft response requirements. The soft-hub rotor concept has universal applications for rotor systems allowing co-planer BMR rotor configura-tions with 3, 4, 5, 6, and 7 blades. A Phase II proof-of-concept, scaled wind tunnel test would prove the soft hub capabilities and generate a data base for full scale design.

Potential Commercial Applications: The system would be of value to military and civilian rotorcraft industries.

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025 ARC
89-1-02.07-3944 NAS2-13125
General Time-Domain Unsteady Aerodynamics of Rotors
Johnson Aeronautics
P.O. Box 1253
Palo Alto, CA 94302
Wayne Johnson (415-325-3944)

A general theory for the time-domain unsteady aerodynamics of helicopter rotors will be developed. The wake theory gives a linearized relation between the downwash and the wing-bound circulation in terms of the impulse response obtained directly in the time domain. This approach makes it possible to treat general wake configurations. The impulse response can be related to the influence coefficients of a trim-wake model, allowing direct use of sophisticated wake models developed for the trim-loading problem. The development will encompass implementation of the wake theory and include model order reduction and identification of a differential equation representation. The result of this activity would be an approach for analyzing aeroelastic behavior while retaining the

important influence of the complicated wake configuration.

Potential Commercial Applications: The resulting analysis would support research, design, and evaluation of advanced rotorcraft configurations.

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026 LaRC
89-1-02.08-0371 NAS1-19026
A High-Temperature, Directional, Spectral Emissivity Measurement System
Information & Control Systems, Inc.
28 Research Drive
Hampton, VA 23666
Nesim Halyo (804-865-0371)

In addressing the need for wind tunnel instrumentation to measure temperature and heat flux in the range 1500°C to 3000°C, this project is developing a new, high-temperature, directional, spectral emissivity-measurement system based on a special integrating-sphere configuration. With known directional, spectral emissivity, the temperature is directly obtained from the emitted flux. Current systems determine emissivity only in the normal direction by measuring the emitted flux, which is highly sensitive to temperature uncertainties. The proposed approach measures the reflected energy, which is insensitive to sample temperature uncertainties. It can determine the emissivity in any direction from normal to 80 degrees, in the wavelength region from 0.25 microns to 25 microns, and from room temperature to 3000°C with a theoretically established accuracy (to be confirmed experimentally). The measurement procedure and theoretical accuracy will be validated experimentally at temperatures reaching 3000°C by testing the integrating sphere configuration with other essential equipment in an experimental measurement system. In Phase I, feasibility will be demonstrated at room temperature; Phase II would be directed toward a demonstration at high temperatures.

Potential Commercial Applications: Applications would be in hypersonic wind tunnels, infrared imaging, and thermal laboratory equipment for jet propulsion, nuclear reactor technology, and solar energy.

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*** 027** LaRC
89-1-02.08-0655 NAS1-19022
Cross-Correlation, Optical Strain Sensor for Wind Tunnel Test Instrumentation
American Research Corp. of Virginia
P.O. Box 3406
Radford, VA 24143-3406
Adel Sarrafzadeh (703-731-0655)

Wind tunnel testing requires instrumentation that is rugged, reliable, and accurate and that provides test data quickly to the test operator. Measurements of static and dynamic strains and proof testing on aerospace structural models are performed in various types of wind tunnels. The typical strain sensors used in such applications at very high temperatures have inherent limitations such as signal reproducibility and incompatibility with the test surface. The laser speckle-based, cross-correlation strain sensor addresses these problems by providing a flexible, noncontacting system for evaluating the large static and dynamic strain fields on the surface of advanced structural materials at temperatures of 1100°C and higher. Phase I will identify high-temperature, high-level strain measurement requirements; configure a rugged, interrogating optical system; integrate solid-state imaging devices; assess test data; and design a proof-of-concept, cross-correlation, optical strain sensor for development and extensive testing in Phase II.

Potential Commercial Applications: Potential applications are in various types of wind tunnels within the commercial aerospace manufacturing industries.

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*** 028** LaRC
89-1-02.09-9282 NAS1-19023
General Flow-Field Analysis Methods for Helicopter Rotor Aeroacoustics
Continuum Dynamics, Inc.
P.O. Box 3073
Princeton, NJ 08543
Alan J. Bilanin (609-734-9282)

The importance of reducing the noise emitted by helicopter rotors has been widely recognized for many years. Previous work in this field has led to the development of an efficient and accurate Lagrangian simulation of the unsteady vorticity field in the vicinity of the main rotor. It could serve as the foundation for a general analysis of the noise generated by main-rotor-wake and tail-rotor interactions. This simulation, a technology demonstration for a limited class of interactions, must be considerably enhanced before it can become a generally applicable tool for the prediction of rotor noise. The overall objective of this project is to demonstrate techniques for generalizing the existing analysis so it can address broad classes of rotor-wake and rotor interaction phenomena, particularly those that figure in main rotor noise generation. These enhancements focus on the expansion of the reconstruction program to handle arbitrary vortex wake intersections of three-dimensional regions around or near main rotors, the development of new nearfield velocity corrections for such interactions, and a preliminary study of methods for using the new high-resolution flow-field analysis for acoustic predictions.

Potential Commercial Applications: A general predictive capability for noise due to rotor-wake and rotor interactions would aid in the design of helicopters to meet both civil and military noise specifications.

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029 MSFC
89-1-02.09-9391 NAS8-38452
The Applications of Fractional Calculus to Noise Simulation
Engineering Analysis, Inc.
715 Arcadia Circle
Huntsville, AL 35801-5909
Frank B. Tatom (205-533-9391)

The realistic stochastic simulation of noise processes is important in a number of areas. These include aircraft and helicopter noise, electro-optical sensor (1/f) noise, atmospheric background noise for scanning systems, atmospheric turbulence for flight training simulation, ocean background noise for sonar systems, and seismic noise for the detection of underground explosions. Unfortunately, the most rigorous stochastic models are often characterized by spectra with certain irrational properties. Previously such spectra could only be approximated in the stochastic generation process. By the application of fractional (non-integer) derivatives in the time domain, improved difference equations may be obtained which will permit new noise generation techniques that are more efficient, flexible, and rigorous than their predecessors. Such techniques have the potential for simulating noise series with time-varying spectral properties.

Potential Commercial Applications: Realistic simulations of stochastic noise processes would be valuable design tools during product development and also useful aids for training operating personnel. Such simulations may also lead to advanced techniques for detecting target signals under low signal-to-noise conditions.

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* **030** LeRC
89-1-02.10-7070 NAS3-25829
Computer Simulation and Design of Jet-Noise Suppressors
Aerochem Research Laboratories, Inc.
P.O. Box 12
Princeton, NJ 08542
Charles H. Berman (609-921-7070)

Computational, rather than experimental, methods are proposed to develop, design, and test the noise suppressors that will be needed to quiet the jet turbulence noise produced by the High Speed Civil Transport and other supersonic vehicles. The viability of this approach is due to recent advances in turbulence theory and numerical methods. These combine renormalization-group methods and spectral-element techniques so that fully three-dimensional, time-dependent flows can be treated at high Reynolds number. Phase I will focus on user-friendly procedures for specifying the coordinates of the suppressor nozzles and the computational grid. The turbulent jet flows of several complex, three-dimensional nozzles will be computed using time-averaged turbulent transport methods. Fully time-dependent computations of turbulence and the near- field sound will be performed for planar nozzles both with and without upstream excitation. This approach will lead to more rational and systematic methods for the optimization of jet-noise suppressors and allow simulation at conditions inaccessible to laboratory test facilities.

Potential Commercial Applications: The results of this project may be applicable to problems involving turbulent mixing, including mixing of hot and cool gas streams to reduce infrared signatures, fuel and oxidizers, and reactants in any chemical synthesis system.

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03: Aircraft Systems, Subsystems, and Operations

* **031** LeRC
89-1-03.01-2403 NAS3-25836
Eddy Current Repulsion De-Icing Strip
Electroimpact, Inc.
2721 N.E. Blakeley Street
Seattle, WA 98105
Peter Zieve (206-525-2403)

This project addresses an innovative devicing system suitable for composite leading edges of aircraft. Helicopter rotors, engine inlets as well as many recently designed aircraft are made of composite materials. The concept consists of a thin spiral coil encapsulated in an elastomer and bonded to the composite leading edge. A thin metal strip is formed across the leading edge over the coil. A bank of capacitors discharges through the coil, inducing eddy currents in the thin metal strip and creating the impulse devicing force. The outer strip serves as a surface for the collection and shedding of ice and does not require any structural properties. The eddy-current repulsion devicing strip concept has five advantages. Stress and fatigue effects are limited to the replaceable, outer metal strip. It would be easy to retrofit since there is no impact on aircraft design or structure. It provides a tough, erosion-resistant metal leading edge. There would be little electromagnetic interference due to the shielding effect of the metal. Ice does not adhere to metal as well as to elastomer.

Potential Commercial Applications: This product may aid in the certification of numerous aircraft for use in known icing conditions.

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* **032** LaRC
89-1-03.02-8533 NAS1-19010
Lightning Protection Technology for Smaller General Aviation Aircraft
Stoddard-Hamilton Aircraft, Inc.
18701 58th Avenue, N.E.
Arlington, WA 98223
J. A. Plumer (206-435-8533)

Lightning protection technology for general-aviation aircraft employing composite materials recently achieved FAA-type certification under Part 23 regulations. This may make it possible to engineer a cost-effective protection method for small, general-aviation

aircraft constructed of composite materials and for their digital avionics. The approach is to evolve a prediction technique which can be used to design a lightning protection system for the Glasair, a factory-built, aircraft kit. Produced by Stoddard-Hamilton Aircraft, Inc., about 1000 kits have been sold. The goal will be to provide a design that will, in the event of a lightning strike, protect the structure from catastrophic failure, protect the occupants, and prevent a fuel system fire.

Potential Commercial Applications: The lightning protection method has commercial prospects for factory-produced aircraft kits, for remotely piloted aircraft, for high-performance gliders, and new general-aviation aircraft constructed of composite materials.

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033 LaRC
89-1-03.03-8228A NAS1-19009
An Improved Methodology to Assess Departure Susceptibility Versus Agility
Eidetics International, Inc.
3415 Lomita Boulevard
Torrance, CA 90505
Joseph R. Chody (213-326-8228)

This project will investigate new and innovative criteria to evaluate the relationship between departure susceptibility and agility of several modern fighter aircraft. The criteria consider high-angle-of-attack stability requirements and the controllability limits of agile combat maneuvers. One aspect of the effort will be an analytical assessment of the F-18 HARV aircraft to be performed in parallel with the F-18 high-angle-of-attack flight test program. The results of this project will be design methodologies which quantify the trade-offs that must be considered in designing an aircraft having optimal agility but with a high level of departure resistance.

Potential Commercial Applications: The new design criteria will define minimum requirements for stability and controllability for aircraft capable of agile, high-angle-of-attack maneuvering.

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* **034** ARC
89-1-03.05-5355 NAS2-13132
Real-Time Adaptive Identification and Prediction of Flutter
Scientific Systems, Inc.
500 West Cummings Park Suite 3950
Woburn, MA 01801
Shahjahan Mahmood (617-933-5355)

The existing methods for the identification and prediction of flutter-damping characteristics are not sufficiently accurate or fast enough for real-time wind tunnel or flight testing. The objective of this project is to demonstrate that recent developments in system identification and model structure determination can be developed into reliable and automatic software on microprocessors for the identification, tracking, and prediction of changing flutter characteristics. Demonstration of feasibility includes modifying system-identification and structure-determination algorithms to handle changing systems, applying simultaneous confidence bands for prediction of flutter damping characteristics, testing the modified algorithms with flutter data, and evaluating computational and storage requirements for microprocessor implementation. The anticipated results are the demonstration of an algorithm suitable for microprocessor implementation which reliably and automatically identifies, tracks, and predicts the changing flutter dynamics.

Potential Commercial Applications: Possible applications for the technology are in chemical process control, control and identification of power plants, and adaptive control in industrial manufacturing.

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* **035** ARC
89-1-03.05-7093 NAS2-13023
Flight Instrumentation for Simultaneous Detection of Flow Separation and Transition
Analytical Services & Materials, Inc.
107 Research Drive
Hampton, VA 23666
Siva M. Mangalam (804-865-7093)

A portable data acquisition and instrumentation system (DAISY), developed by the company for use in wind-tunnel tests, accurately identifies and demarcates regions of flow separation and reattachment and the leading-edge stagnation point. Simultaneously, it also determines laminar-to-turbulent transition and the spectral content of the most amplified disturbances in the boundary layer. This project will apply this powerful technique in a simple, portable, effective, real-time, in-flight, flow-diagnostic tool. A sailplane will be used during Phase I of the project for the in-flight detection of the surface boundary-layer characteristics. Multi-element, non-intrusive, hot-film sensors will be installed on the wing. A light-weight, compact instrumentation package consisting of a bank of constant temperature anemometers, signal conditioners, and a micro-computer-based data acquisition system similar to DAISY will be used. The instrumentation system and the associated software package will be designed as a general purpose diagnostics tool for a variety of flight-test applications. High-speed applications would occur during Phase II using a suitable aircraft.

Potential Commercial Applications: The product would be an instrumentation system for flight-test applications.

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036 LaRC
89-1-03.06-0533 NAS1-19006
Low-Cost, Angle-of-Attack Sensor for Subsonic Aircraft
Innovative Dynamics
244 Langmuir Lab, Cornell Research Park
Ithaca, NY 14850-1296
Joseph J. Gerardi (607-257-0533)

The objective of this project is to develop a low-cost, smart, angle-of-attack and angle-of-sideslip

sensor (SAASS). The design has a fixed-position sensing element capable of measuring velocity heading and flow direction over a complete 360-degree angle. This will produce a three-axis velocity vector that will enable the determination of angle-of-attack and angle-of-sideslip. Use of a microprocessor in the SAASS will allow digital compensation for airflow temperature and pressure to calculate absolute velocity. A prototype airflow sensor with an angular sensitivity of one degree will be designed, fabricated, and tested during the Phase I effort. By combining a simple mechanical design with low-cost CMOS-VLSI circuitry, a probe can be developed at a cost of approximately $200 per unit. The probe, software, and serial interface will be delivered to NASA at Phase I completion for demonstration on a standard personal computer.

Potential Commercial Applications: A low-cost, low-drag, smart aircraft flow measurement instrument would have enormous potential because a device that will determine true airspeed is presently unavailable using conventional pitot-static instrumentation.

***

037 ARC
89-1-03.06-0655 NAS2-13129
Laser-Speckle Interferometer for Surface-Acoustic-Displacement Measurements
American Research Corp. of Virginia
P.O. Box 3406
Radford, VA 24143-3406
Adel Sarrafzadeh (703-731-0655)

Techniques for real-time characterization of the properties of structures and propulsion systems of advanced aeronautical and aerospace vehicles require accurate measurement of dynamic properties. This project will develop a non-intrusive, rugged, optical imaging method compatible with poorly reflecting surfaces of advanced propulsion system components. This approach, based on guided-wave propagation phenomena, can use the Lamb-wave technique, in which measurements of acoustic wave speeds can be directly related to material stiffness properties. The project addresses the detection problems associated with surface acoustical measurements employing optical technology. Technical objectives include identification of elastic wave parameters and testing requirements; evaluation of a rugged, multi-axis acoustic displacement sensor; integration of acousto-optical ultrasonic detection subsystems; assessment of test data; and design of a proof-of-concept system for development and testing in the Phase II program. Successful completion of these objectives will result in instrumentation for monitoring the performance characteristics of flight vehicles.

Potential Commercial Applications: Applications include non-destructive evaluation in industrial processes and dynamic measurements in aircraft testing.

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038 ARC
89-1-03.06-1223 NAS2-13024
Evaluation of PVDF Film as a Pressure Sensor
B&D Instruments and Avionics
209 W. Main
Valley Center, KS 67147
Richard Kreeger (316-755-1223)

This project investigates the feasibility of developing a highly accurate, low-cost polymer sensor utilizing the piezoelectric properties of PVDF combined with a diaphragm and/or other force sensitive structure to produce a pressure sensor. The polymer sensor will be easily adapted to commercial and general-aviation aircraft for sensors utilized in smart angle-of-attack and angle-of-sideslip measurements.

Potential Commercial Applications: Applications cross industry lines. Pressure measurements must be made in most industrial processes.

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039 LaRC
89-1-03.07-8061 NAS1-19011
Ceramic-Matrix-Composite for Hypersonic Engine Structures
Refractory Composites, Inc.
12220-A Rivera Road
Whittier, CA 90606
Edward L. Paquette (213-698-8061)

Advanced composites based on ceramic or carbon matrices are candidates for hot wall structures of hypersonic engines. The advantages of these composites relative to metals are reduced weight, reduced risks of hydrogen corrosion or embrittlement, improved acoustic damping, and higher mean operating temperatures. The higher temperature capability reduces the cooling load imposed on the hydrogen fuel and allows use of warm hydrogen (1400-1600°F) for cooling ceramic-matrix-composite (CMC) structures to (2200-2400°F). Initial development will be conducted on CMC panel structures with integral coolant passages.

Potential Commercial Applications: Cooled CMC wall structures could be applied in heat transfer equipment of interest to energy conversion and chemical process industries.

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040 ARC
89-1-03.08-3226B NAS2-13131
An Advanced Heat Rejection System for an AVCD Engine in a High-Altitude Research Platform
Dieseldyne Corporation
3044 Middleboro Road
Morrow, OH 45152
Richard P. Johnston (513-899-3226)

This project will evaluate the requirements for heat rejection from the various systems of an ultra-high-altitude, advanced variable-cycle diesel (AVCD) installed in an airframe suitable for atmospheric sampling missions. A combination of convective and radiation

heat transport systems will be evaluated and then incorporated into a diesel simulator code for performance evaluation. Configurations and ultimate performance levels will be determined, and an assessment of the installation effects performed.

Potential Commercial Applications: These heat exchanger systems could be applicable to the NASP or supersonic transport aircraft.

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*** 041** ARC
89-1-03.08-5694 NAS2-13158
Propulsion System for a High-Altitude Research Platform
Aurora Flight Sciences Corporation
Box 11998
Alexandria, VA 22312
John S. Langford (703-845-5694)

A fuel-cell-based electric propulsion system for very high-altitude aircraft will be investigated. This system would potentially be capable of reaching altitudes of up to 40 km (131,000 ft) with a scientific payload in excess of 450 kg (1000 lbs). It would be an attractive propulsion alternative for NASA'S proposed High Altitude Research Platform or other very high altitude aircraft. Phase I will design a system that uses either cryogenic oxygen or compressed air as the oxidizer for the fuel cell. The seven tasks to be completed include: fuel cell selection; evaluation of turbocharging concepts; prediction of propeller performance; analysis of electric propulsion drive trains; analysis of cooling requirements; preliminary design of a baseline system; and formulation of results so as to support parametric studies for aircraft sizing and optimization.

Potential Commercial Applications: This project is applicable to high-altitude aircraft needed to support global, climate research.

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042 ARC
89-1-03.08-7121 NAS2-13156
Very-High-Altitude Aircraft with Joined Wings
ACA Industries, Inc.
28603 Trailriders Drive
Rancho Palos Verdes, CA 90274
Julian Wolkovitch (213-539-7121)

This project investigates the application of joined wings to subsonic aircraft designed to fly above 100,000 feet. Joined-wing airplanes employ two sets of wings rigidly connected together to form a triangulated self-bracing structure. Structural analyses and wind-tunnel tests have shown that, compared to cantilever wings, joined wings are lighter, stiffer, and have higher span-efficiency factors, giving lower induced drag. Aircraft flying above 100,000 feet must operate near the drag-divergence Mach number while generating high lift coefficients. For such flight conditions, thin supercritical airfoils are desirable. Cantilever wings employing such thin airfoils tend to be heavy and/or excessively flexible. For joined wings, however, reducing thickness-chord-ratio gives only small penalties in structural weight and rigidity. The net effect is that the joined wing can increase the altitude and payload capabilities of very high altitude aircraft. This project will delineate suitable joined-wing configurations, and will select one configuration for detailed structural and aerodynamic investigations.

Potential Commercial Applications: The results would apply to very-high-altitude aircraft intended for atmospheric sampling or Earth resources surveys and may also yield improvements in range, speed, and payload of transport aircraft.

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*** 043** LaRC
89-1-03.09-1457B NAS1-19021
Methods and Tools for Assessing Limits of System Intelligence
Search Technology, Inc.
4725 Peachtree Corners Circle, Suite 20
Norcross, GA 30092
William B. Rouse (404-441-1457)

Intelligent systems technology is envisioned as being an important component of future aviation and space systems. Expert systems for mission planning, flight control, and flight management are primary examples. While the ability to build intelligent systems has been demonstrated, we do not understand their properties in ways that we understand, for example, control systems. Limitations of the physical and behavioral models that underlie intelligent systems can lead to undesirable behaviors analogous to oscillation and instability in traditional systems. This project will develop methods and tools for analyzing intelligent systems and predicting likely undesirable behaviors. The overall methodology will involve iterative use of analytical and empirical methods to assess internal consistency and external validity, respectively. The eventual product will be computer-based tools for analyzing designs of intelligent systems such as are likely to be part of future NASA systems, as well as a plethora of commercial systems.

Potential Commercial Applications: Computer-based tools for assessing intelligent systems could be applied in aviation, space, manufacturing, power, and process industries.

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*** 044** ARC
89-1-03.10-0753 NAS2-13130
A Knowledge-Based Simulation Design, Development, and Coding Environment
G & C Systems, Inc.
30250 Rancho Viejo Road, Suite B
San Juan Capistrano, CA 92675
David M. Tartt (714-248-7212)

This project involves the development of a knowledge-based environment for simulation design, development, and coding. This software development environment would provide a common user interface, knowledge base, and data base for all computers used at NASA-Dryden to develop and code simulations. The

environment would encourage the development of portable code. This would be accomplished by encouraging the user to select routines and/or routine formats from a data base and by employing automated code generation and code conversion programs. Coding practices which inhibit and promote portability would be made readily available on the system documentation. The environment would allow the user to build a simulation by responding to prompts from the system. The user would be allowed to access code, subroutines, or complete programs from other simulations as required. The innovation would significantly reduce the cost of developing simulations and of rehosting them in other computers.

Potential Commercial Applications: The product could apply throughout the aerospace community in modeling and simulation for system design and analysis. It could save time and money in developing and rehosting simulations and exchanging them among contractors and government agencies.

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04: Materials and Structures

045 LeRC
89-1-04.01-1980A NAS3-25630
A Coated, Titanium Diboride, Whisker-Toughened, Silicon Carbide Matrix Composite
Materials and Electrochemical Research
7960 S Kolb Road
Tucson, AZ 85706
J. C. Withers (602-574-1980)

Silicon carbide is a very desirable structural ceramic, but state-of-the-art monoliths lack toughness and reliability. Whisker toughening has not been effective due to the disappearance of the SiC in the very-high-temperature consolidation process. Titanium diboride particles have demonstrated stability in the SiC consolidation process but do not have a major impact on increasing toughness and lack oxidation stability above about 1200°C. This project will explore the use of TiB_2 whiskers that should substantially increase toughness and apply a Y_2O_3 coating to the TiB_2 whiskers that should provide oxidation protection above 1400°C. The target properties are ≥8 MPam toughness and 800 MPa strength above 1400°C. Rigorous and unique processing will be utilized to avoid large particles or agglomerations to produce a theoretical dense composite with flaw sizes less than the critical size.

Potential Commercial Applications: Toughened, oxidation-stable, TiB_2 whisker-reinforced SiC will have applications in aerospace propulsion and power applications, components for diesel and spark ignition engines, pump seals and parts, nozzles, wear plates, armor, heat exchangers, etc.

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046 LeRC
89-1-04.01-3200 NAS3-25871
High-Temperature, Film-Based Polybenzoxazole/Polymide Microcomposite for Turbine Engines
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02154-1196
Ted E. Kirchner (617-890-3200)

High-temperature composites must be used extensively on aircraft turbine engines to meet high thrust-to-weight requirements on all classes of next-generation aircraft. This project will develop a film-based composite of PBO (poly p-phenylene benzobisoxazole) and PMR-II that will have the properties of high-performance carbon composites without the cost and micro-cracking associated with discrete-fiber and matrix composites. The approach is to introduce the PMR-II into the PBO through an interpenetrating network (IPN) process that assures a homogeneous microcomposite which is impermeable and is highly resistant to delamination. The PBO/PMR-II laminate will be tested at room temperature and up to 650K to verify its high-temperature performance. In the Phase II program, we will bring in a turbine manufacturer to identify a suitable component to fabricate with PBO/PMR-II.

Potential Commercial Applications: Advanced aircraft turbine engine components could be fabricated with high-temperature composites at considerable cost and weight savings. This is also true with internal airframe structures for advanced supersonic aircraft and hypersonic vehicles such as the National Aerospace Plane.

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047 LeRC
89-1-04.01-9049 NAS3-25889
Soluble, Conducting-Polymer-Based Conductive Coatings
Gumbs Associates, Inc.
11 Harts Lane
East Brunswick, NJ 08816
Prasanna C. Sekhar (201-257-9053)

Recent unrelated work by the company has yielded a breakthrough in conducting polymer technology. These polymers are processible and soluble with 6 percent or higher solubility in organic solvents. They produce homogeneous, reproducible thin films with conductivities as high as 1 S/cm. This project will seek to enhance conductivities of these polymers and to synthesize new polymers based on trends identified in the prior work. The work will also attempt to improve solubilizing, processing, and coating techniques. The design of the targeted new polymers includes consideration of environmental stability by exclusion of reactive constituents. Besides the advantages of weight, processibility, their one-component nature and stability, the polymers will also have anticipated superior conductivity compared to currently available composites.

Potential Commercial Applications: Applications of lightweight, processible, and stable conductive coatings include such uses as EMI shielding, IR emissivity and

radar signature reduction, odd-shaped electrodes, electrochromic displays, and ultrafast electro-optic switches.

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048 LeRC
89-1-04.02-0018 NAS3-25824
Probabilistic Structural Mechanics for Parallel Processing Computers
Applied Research Associates, Inc.
6404 Falls Of Neuse Road Suite 200
Raleigh, NC 27615
Robert H. Sues (919-876-0018)

This project will explore the use of parallel processing computers to solve problems in probabilistic structural mechanics (PSM) that arise in the assessment of reliability of complex aerospace structures. PSM problems, solved by Monte Carlo simulation, are inherently parallel and are ideally suited for solution on parallel computers. Relatively little research, however, has been conducted in probabilistic structural mechanics to exploit the power of these machines. The objectives of the Phase I effort will focus on the evaluation, in a parallel computer architecture, of probabilistic Monte Carlo implementation strategies, including pipelining (vectorization), concurrency (multitasking), synchronization, and variance reduction techniques. While much of the research in PSM over the last two decades has focused on basic theory development, the next decade of research in computational PSM may open up a whole new class of finite-element and dynamics problems to probabilistic structural analysis.

Potential Commercial Applications: The solution of probabilistic structural mechanics problems on parallel processing computers will provide direct guidance for probabilistic, reliability-based analysis and design of space, defense, and critical commercial structures.

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* **049** LaRC
89-1-04.03-3200 NAS1-19025
LaRC-TPI and Liquid-Crystal Polymer Blends
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02154-1196
Richard W. Lusignea (617-890-3200)

Spacecraft structures, such as the precision, segmented reflector, truss tubes, and solar cell array panels, require the development of low coefficient-of-thermal-expansion (CTE) polymers with excellent processibility. A blend of novel liquid-crystal polymers (LCPs) with NASA's high-performance thermoplastic polyimide, LARC-TPI is an approach for developing material with properties that meet future requirements for spacecraft. Such blends can reduce CTE by more than a factor of 10 and can increase modulus by more than three times at volume ratios of 30 to 50 percent for the LCP. These materials are much easier to process because viscosity is reduced by two orders of magnitude. Such improvements will make LARC-TPI and LCP blends fully competitive with fiber-reinforced composites but at lower cost. These high-temperature, high-stiffness, low-density, near-zero CTE films and molded parts will make ideal materials for a variety of applications, such as high-strength, high-stiffness, thin-walled space structures and precision, segmented reflectors for solar collectors.

Potential Commercial Applications: Applications may include antenna and reflector structures, solar array panels, thermal insulation layers, self-deployable structures, thermally stable interlayers for components used for direct surface mounting and multilayer board construction, and high-temperature vacuum bagging films for composite fabrication.

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050 LaRC
89-1-04.03-5325 NAS1-19002
Multi-Angular Weaving for Composite Preforms
Textile Technologies, Inc.
2800 Turnpike Drive
Hatboro, PA 19040
Steve Walker (215-443-5325)

The need to reduce labor expenses for the production of advanced composite preforms has been a major issue in the composite industry. The ability to weave angular yarns integrally, with standard warp (0 degree) and filling (90 degree) yarns, would be an asset. Currently, labor-intensive, off-axis hand lay-ups are used to produce multiangular preforms. This project will develop a concept to produce composite preforms with off-axis fibers. In addition, this concept will not crimp or impale fibers.

Potential Commercial Applications: The development of this technology would reduce cost and improve mechanical properties of composite preforms. Such technology would advance the U.S. in the composite industry.

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* **051** LaRC
89-1-04.03-8072 NAS1-19013
Methods for Producing Fine-Particle, Thermoplastic Polyimide Sulfone Powder
High Technology Services, Inc.
250 Jordan Road, Suite 210
Troy, NY 12180
Milton L. Evans (518-283-8072)

This project will design and develop innovative methods for producing powders of polyimide sulfone polyamic acids as well as the polyimide sulfone. These materials are becoming well known in the scientific and industrial communities for their array of outstanding properties, including thermoplasticity. However, to exploit these properties fully, the materials must be available in forms which allow diverse processing options. One form which allows many options is the powder form. While several polyimides, such as LARC-TPI powder, are available and being evaluated extensively, polyimide sulfone powder with particle sizes of 10-20 microns is not available. Several major aerospace companies and NASA materials organizations

are keenly interested in evaluating these powders in composite and adhesives applications. This project will develop production techniques and supply developmental quantities to appropriate firms.

Potential Commercial Applications: Polyimide sulfone thermoplastics are being evaluated as matrix resins and adhesives for applications in aircraft and space vehicles. These include fuselage and engine parts as well as adhesives for other polyimide composites.

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052 LeRC
89-1-04.04-0236 NAS3-25886
CVD Chromium-Diboride Fibers for Metal-Matrix Composites
Ultramet
12173 Montague Street
Pacoima, CA 91331
Andrew J. Sherman (818-899-0236)

Ever-increasing design and performance requirements escalate the demands on materials for gas turbine applications. The operational capabilities of the superalloys have increased dramatically in the last decade, but further increases can be achieved only through the addition of second-phase reinforcements. Acceptable reinforcements, however, are not yet available due to drawbacks such as high density, low thermal expansion, and poor oxidation resistance. Chromium diboride (CrB_2) has a CTE matching that of superalloys, good oxidation and corrosion resistance, high modulus, reasonable density, and potentially high strength suitable for superalloy reinforcement. Phase I will demonstrate the feasibility of producing continuous, high-strength CrB_2 monofilaments by chemical vapor deposition on a suitable wire substrate and evaluate its stability in contact with various superalloys through the use of diffusion couples. Specific program goals include developing a fine-grained, microcrystalline CrB_2 mono-filament with a strength in the 100-200 ksi range and evaluating its thermal and mechanical properties.

Potential Commercial Applications: CrB_2-reinforced superalloys will find use in various jet propulsion components including combustion liners, afterburner liners, exit nozzles, turbine shrouds, blades and vanes, among others.

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053 LeRC
89-1-04.04-5444A NAS3-25872
Rapidly Solidified, Narrow, Titanium-Aluminide Strip
Ribbon Technology Corporation
P.O. Box 30758
Gahanna, OH 43230
Mark Farrell (614-864-5444)

NASA Lewis Research Center has developed an arc spray process which can fabricate laminated titanium-aluminide composites using titanium-aluminide wire to form the matrix. This is a significant materials advance in high-strength, high-temperature properties with reduced weight. A major limitation to the application of this process has been the brittleness of conventionally formed titanium-aluminide wire and its high cost. The company will seek to direct-cast rapidly solidified titanium-aluminide strip for use in place of wire to gain the following advantages: improved ductility, longer lengths of strip, and improved process economics.

Potential Commercial Applications: Aerospace applications for thin, advanced, intermetallic strip will open up as manufacturability and cost efficiencies are demonstrated.

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054 LeRC
89-1-04.04-8044 NAS3-25838
Microstructurally Toughened, Intermetallic Matrix Composites
Cordec Corporation
8270-B Cinder Bed Road -- P.O. Box 188
Lorton, VA 22079-0188
Raymond J. Weimer (703-550-8044)

Hypersonic flight vehicles and engines depend upon development of new, high-temperature, metal-matrix-composite (MMC) materials. Fiber-reinforced, titanium-aluminide alloys have great potential to meet the engineering requirements of such structures. Considerable effort has gone into developing these MMCs with large-diameter, silicon-carbide fibers (5.6 mil monofilaments), and mechanical properties have been impressive. However, the toughness has been too low for damage-tolerant structural applications. The manufacture of MMCs by vapor deposition offers the prospect of producing polyphase microcomposite precursors in the form of continuous monofilaments or thin monotapes. This would contain fiber in the desired volume fraction with diffusion barriers, a titanium-aluminide matrix, and a ductile, high-temperature interphase for crack arrest. Phase I will establish the feasibility of such MMC monotapes; demonstrate thin-gauge composite panels consolidated from such tapes; and develop preliminary process, structure, and property relationships to establish their potential for structural use at temperatures above 1000°C. Phase II would demonstrate pilot scale production of precursors and fabricability of complex structural shapes.

Potential Commercial Applications: This material could be extremely attractive for advanced commercial aircraft turbine engine components where weight savings of more than 50 percent are possible compared to superalloy components.

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055 LeRC
89-1-04.05-7351 NAS3-25879
Advanced Finite-Elements for Structural Analysis
CSA Engineering, Inc.
560 San Antonio Road, Suite 101
Palo Alto, CA 94306-4682
Warren C. Gibson (415-494-7351)

Many industrial firms in the United States, particularly the aerospace and automotive industries, rely heavily on finite-element structural analysis. This project should improve the returns on this investment by providing more accurate results and reduced computing times. It is based on an approach called the integrated force method (IFM). Like the standard force method, the IFM offers increased accuracy, especially in stress calculations, but does not require selection of redundants. The present approach uses a derivative of the IFM, called the dual-IFM. The dual formulation preserves most of the benefits of the IFM within the context of a displacement-based, finite-element computer program. This makes it possible to introduce new IFM elements into a code like NASTRAN with minimal disruption, thus taking advantage of most of the existing facilities of NASTRAN. Some preliminary results are available for simple plate bending test problems. The discretization errors shown by the new elements are considerably smaller than those produced by two established codes, ASKA and MSC/NASTRAN, by factors of five or more.

Potential Commercial Applications: This development has potential for commercial applications in the strong market for finite-element software.

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*** 056** LaRC
89-1-04.06-0318 NAS1-19032
Digital, Optical Phase-Lock-Loop for Non-Destructive Evaluation
Systems & Processes Engineering Corp.
1406 Smith Road, Suite A
Austin, TX 78721
Gary B. McMillian (512-385-0318)

The company has developed an innovative design for a digital, optical phase-lock-loop (DOPLL) for measurement of strain, displacement, or vibration in non-destructive evaluation applications. The technique offers a number of advantages over previous analog phase-lock-loop designs. The digital system is capable of seeking multiple lock-points under software control and successively refining the measurement precision by seeking lock points at higher modulation frequencies. The digital system has a broad operating bandwidth through use of a digital frequency synthesizer in place of a bandwidth-limited voltage-controlled oscillator. The digital system is capable of significantly faster operation, since the precise modulation frequency is known at phase lock and no precision measurement is required to determine frequency. The design is relatively insensitive to the path of the intensity-modulated light, and a common DOPLL path length measurement system can be utilized with a number of sensor types, each connected via fiber optics.

Potential Commercial Applications: The DOPLL design can be utilized for non-destructive evaluation and monitoring of aging aircraft structural integrity. The basic DOPLL design also has applications in direction finding, beam steering, and communications.

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*** 057** LaRC
89-1-04.06-0533 NAS1-19014
Aircraft Health Monitoring System
Innovative Dynamics
244 Langmuir Lab, Cornell Research Park
Ithaca, NY 14850-1296
Gail A. Hickman (607-257-0533)

The company has developed a unique, thin-film sensor design that when integrated with a structural member could detect fatigue cracks, corrosion, and ice accretion as well as external pressure variations indicative of an impending wing stall. These sensors and signal processing software can be integrated into an advanced health monitoring system (HMS) to extend significantly the life span of the aging, commercial aircraft fleet. Based on the concept of smart structures, the HMS is designed to emulate the human nervous system. An array of sensors ("nerves") located throughout the aircraft structure will be connected by a common data bus or network to a signal processing chip ("brain"). The HMS will continuously scan sensor arrays integral with the aircraft skin. By monitoring the structural vibration signatures induced under normal aerodynamic loading, the HMS will determine structural abnormalities through pattern recognition techniques. When an abnormality is detected, the system will identify it, log the time and location, and issue a warning. This system has the potential for lifetime monitoring of structural properties and providing real-time, non-destructive evaluation in flight.

Potential Commercial Applications: In addition to extending the life of commercial aircraft, this technology may also find application in monitoring strain in large structures, such as buildings, ships, storage tanks, dams, bridges, and in monitoring earthquakes.

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*** 058** MSFC
89-1-04.08-6381 NAS8-38463
Portable Spectroreflectometer
AZ Technology, Inc.
3322 Memorial Parkway, SW, Suite 93
Huntsville, AL 35801
Donald R. Wilkes (205-880-7481)

Future space missions place stringent requirements on materials used on space vehicles. The spectral reflectance properties of materials are critically important for controlling manufacturing processes and assessing effects of exposure to ground handling and the space environment. Current instruments for measuring spectral reflectance are high-resolution laboratory devices that apply to small samples. In many applications, it is undesirable or impossible to remove a small sample for laboratory evaluation. The objective of this project is to develop the conceptual and functional design for a portable spectroreflectometer to measure spectral reflectance of extended surfaces. This instrument will use a prism monochrometer and an integrating sphere to provide total hemispherical reflectance measurements from 0.25 to 2.5 μm. Configurations will be developed for a hand-held unit for both ground and space use and for a remotely

operated unit suitable for use on orbit with a remote manipulator system. (Note: Phase I contract awarded to John M. Cockerham & Associates, Inc.)

Potential Commercial Applications: This instrument could be applied in optical and thermal surface process control; in-process monitoring; receiving and preflight inspection; on-site evaluation of surfaces; materials R&D; and paint and surface treatment development.

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059 LaRC
89-1-04.09-5444 NAS1-19019
Process Control for Melt-Overflow, Rapid Solidification Technology
Ribbon Technology Corporation
P.O. Box 30758
Gahanna, OH 43230
Thomas Lease (614-864-5444)

A promising new technique for directly casting rapidly solidified titanium alloy ribbons for airframe honey-comb structures was developed by the company with NASA support. The plasma-melt-overflow process combines transferred plasma-arc, skull-melting techniques and melt-overflow, rapid-solidification technology to cast directly ribbons and strip that are amenable to processing to foil gauges. In this project, the company will control the as-cast strip's physical dimensions and increase the melt size through four innovative techniques: redesign of the water-cooled, copper hearth used to contain the liquid titanium; control of the hearth pouring rate; monitor and control the hearth water-cooling system; and use metallic insulating mats between the titanium skull and hearth as a barrier to heat transfer. If successful, these four techniques will both increase the amount of liquid titanium that can be melted by the plasma-arc, skull-melting process and improve the dimensional uniformity of the titanium alloy ribbons cast by the melt-overflow, rapid-solidification process.

Potential Commercial Applications: The ability to achieve direct-cast, thin metallic strip or foils opens up a wide range of applications in the aerospace or commercial industries which use advanced, light-alloy metallic structures.

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060 MSFC
89-1-04.10-6576 NAS8-38447
A Mathematical Model To Investigate Undercutting and To Optimize Weld Quality
CFD Research Corporation
3325-D Triana Boulevard
Huntsville, AL 35805
H. Q. Yang (205-536-6576)

This project is aimed at providing plausible explanations for the undercutting feature of welds. A mathematical model will be developed to simulate weld pool motion. Particular emphasis will be placed on the variation of surface tension with temperature and local concentrations of oxygen and other impurities that may diffuse to the weld pool surface through shield gas. The spatial variation of concentration, which is expected to be quite significant, will be properly accounted for. Such variation has the potential of causing secondary eddies in the weld pool and, hence, the undercutting feature on the surface. In Phase I, the model will be developed by adapting an existing CFD code, and a parametric study will be performed to establish the proof-of-the-concept. In Phase II, the adapted code will be improved, validated, and documented for use in NASA and the welding industry.

Potential Commercial Applications: The mathematical model and computer code could become an industry standard for optimization of weld conditions and parameters. Such a capability is crucial for the success of automation of welding processes.

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*** 061** MSFC
89-1-04.10-7900 NAS8-38448
Macro- and Task-Level Programming of Arc Welding Robots for Aerospace Applications
Automatix, Inc.
755 Middlesex Turnpike
Billerica, MA 01821
John E. Agapakis (508-667-7900)

The goal of the overall project is an innovative programming environment for the next generation of advanced welding robot controllers. This environment will incorporate macro-level programming, icons for user interfaces, graphical simulation, and, possibly, elements of task-level programming, e.g., automatic path planning and weld sequence optimization. Macro-level programming, aspects of which will be considered in Phase I, refers to the generation of complex part programs from primitives which encapsulate all the required motions and operations needed to weld generic classes of parts, components, or joints. Such developments could significantly improve productivity and consistency of teaching welding robot programs and impact the cost and reliability of robotic welding in aerospace application. Phase I tasks include: a brief review of related work, analysis of welding requirements for aerospace fabrication, preliminary design of the advanced programming environment, and evaluation of macro-level programming approaches. The feasibility of the proposed schemes will be examined, needs for future research will be identified, and the Phase II effort will be planned.

Potential Commercial Applications: Advanced welding robot controllers may benefit commercial low-volume, small-batch, robotic welding applications.

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062 GSFC
89-1-04.11-3812 NAS5-30809
New Perfluoropolyether Elastomers for Low- and High-Temperatures
Exfluor Research Corporation
P.O. Box 7807
Austin, TX 78713-7807
Hajimu Kawa (512-454-3812)

The company has developed a technology to fluorinate high-molecular-weight hydrocarbon polyethers. A wide variety of perfluoroalkylether elastomeric polymers exhibiting excellent low-temperature flexibility have been prepared. Some of those perfluoropolyether elastomers were found to have glass transition temperatures as low as -100°C. However, none of those polymers has the good processability required in commercial applications. Perfluorinated polymers have such low molecular interactions that they do not stick together very well as most hydrocarbon and partially fluorinated polymers do. The lack of reactive sites in those perfluoropolyether elastomers makes it impossible chemically to cross-link the polymers. Efforts will be made to solve the above processability problems by introducing some functionality into perfluoropolyether elastomers using recently developed fluorination techniques. The physical properties of the polymers will be studied by thermogravimetric analysis and differential scanning calorimetry.

Potential Commercial Applications: Elastomeric polymers based on perfluoropolyether structures that are capable of retaining their elasticity at low temperatures (-100°C), while exhibiting oxidative and thermal stability at high temperatures (400°C), could solve many materials problems and be fabricated into O-rings and other seals.

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063 GSFC
89-1-04.11-5911 NAS5-30858
Improved Electro-Rheological Fluids for Lubricant Viscosity Control
Cape Cod Research, Inc.
P.O. Box 600
Buzzards Bay, MA 02532
Francis Keohan (508-759-5911)

The company will produce novel, structured copolymer material that promises to advance the state of electro-rheological (ER) fluid technology. The new system will provide the electrovicous response of conventional ER fluids without their temperature sensitivity and physical instability. The new ER fluids will give controllable lubricant properties over a broad temperature range, will have outstanding mechanical stability, and will be non-corrosive to metal parts. This fundamentally different approach to controlling rheological properties will represent a significant step in the commercialization of ER lubricants.

Potential Commercial Applications: The proposed ER fluid technology could have applications in the lubrication and hydraulic processes of future space-craft, aircraft, automobiles, heavy machinery and robotic systems.

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*** 064** GSFC
89-1-04.11-7412 NAS5-30855
A Composite Material Flywheel for Energy Storage
FARE, Inc.
4716 Pontiac Street, #304
College Park, MD 20740
Douglas M. Ries (301-982-2093)

An innovative composite-material flywheel design suited for the GSFC/UOM, magnetically suspended, energy-storage flywheel rotor will be developed. The rotor is an interference-assembled (i.e., prestressed) collection of composite-material, thin rings that, when assembled together, collectively form a thick ring flywheel rotor. There are no spokes or stress concentration geometries on this rotor, and, with proper design, the specific energy densities of the rotor can approach their theoretical design limit. The rotor can operate reliably with minimum containment. Rotor stresses will be computed, and performance will be optimized. Fabrication methodologies and composite-material properties will be investigated with the end objective of selecting the most suitable materials and fabrication method to prepare and cure the composite rotor.

Potential Commercial Applications: Applications of high-strength, fatigue-resistant composites include flywheels for space energy storage and attitude control and ultra-high-strength, high-reliability pressure vessels and missile casings.

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*** 065** JPL
89-1-04.12-2332 NAS7-1079
Miniature, Thin-Film Deposition System
ISM Technologies, Inc.
9965 Carroll Canyon Road
San Diego, CA 92131
James R. Treglio (619-530-2332)

NASA's CRAF probe will use a scanning electron microscope for analysis of the dust from comets. As the dust is not likely to be conducting, some means must be found to apply thin films (20 nanometers) to the surfaces of micron-sized dust particles without heating them excessively. The firm will adapt its patented MicroMEVVA, a miniature metal-ion source, to produce a metal-ion plasma and directly deposit thin films of conducting metals onto dust particles. The MicroMEVVA is particularly suited to the space application because it requires no carrier gas, works with many stable metals, does not require heating of the surface to be coated to achieve good adhesion, and has no moving parts. In addition, it has already been tested in a three inch size, so it is readily miniaturized for this mission. A wide variety of metals can he deposited, including the noble metals such as platinum and rhodium.

Potential Commercial Applications: A small deposition source could be used for coating complex surfaces that cannot be reached by conventional systems and as an ion source, allowing ion implantation of complex shapes and interior surfaces as well. A large array of

small sources could serve to replace a single, larger source for treating fibers and other objects.

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066 JSC
89-1-04.13-8044 NAS9-18313
New Fabrication Methods for Dimensionally Stable, Graphite-Magnesium Space Structures
Cordec Corporation
8270-B Cinder Bed Road -- P.O. Box 188
Lorton, VA 22079-0188
Raymond J. Weimer (703-550-8044)

In fabricating thin-gauge graphite in magnesium composites, the firm has produced the first such material to have a zero coefficient of thermal expansion and no perceptible dimensional hysteresis during cycling over the entire orbital temperature range of -155°C to +140°C, even after 100 cycles. Coupled with density of less than 2 grams per cubic centimeter, a tensile strength over 70 ksi, and a Young's modulus over 50 Msi, this thermal expansion behavior makes the material extremely attractive for large, orbiting space structures. This project seeks to develop techniques for fabricating thin-gauge, net-shape components in complex geometries and facilitating joining into such structures. Phase I will establish feasibility of using a novel isostatic pressurization system to mold such components; Phase II would develop full-scale prototype components for evaluation.

*Potential Commercial Applications:*These new graphite-in-magnesium composites are well-suited for many anticipated structural applications in space stations, antennas, vehicles, and platforms.

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* **067** JPL
89-1-04.14-0540 NAS7-1091
Magnetostrictive, Active-Member Control of Space Structures
Satcon Technology Corporation
12 Emily Street
Cambridge, MA 02139-4507
Bruce G. Johnson (617-661-0540)

Large space structures--characterized by low natural frequencies, lightly damped structural modes, and stringent shape control requirements--pose unique and difficult control problems. One promising approach uses active truss members that incorporate sensors and actuators and allow both closed-loop control of the space structure shape and suppression of unwanted structural vibrations. In the past, these active truss members have incorporated piezoelectric or electrodynamic actuators. Recent developments in magnetostrictive materials, however, offer the opportunity for increased strain, increased power density, and decreased hysteresis compared to piezoelectric materials. For example, maximum strains and power densities can be over an order of magnitude higher than for piezoelectric materials. Innovations are needed, however, to integrate these high-performance magnetostrictive materials into active truss members. This effort will develop advanced active truss members based on magnetostrictive materials including the associated sensors and controller.

Potential Commercial Applications: Active structure control could be applied in vibration absorption, vibration isolation, and noise control for inertial instrument test tables, crystal growing, optical test benches, and vibration reduction in large mechanical systems.

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068 JSC
89-1-04.15-0540 NAS9-18331
Direct Measurement of Bolt Tension Utilizing Magnetostriction
Satcon Technology Corporation
12 Emily Street
Cambridge, MA 02139-4507
James H. Goldie (617-661-0540)

A new method for measuring bolt tension directly exploits the relationship between stress and magnetic flux density in magnetostrictive materials. A conventional washer is either replaced or supplemented by a washer made from a magnetostrictive alloy. A wrench modified to include a Hall-effect probe and a permanent magnet is utilized to monitor the change in magnetic flux due to compression of the washer. This represents an improvement over current techniques in that the compressive force on the washer is a direct measure of the tension in the bolt. Consequently, calibration to account for bolt parameters such as length, stressed length, diameter, velocity of sound, tensile stiffness, and surface characteristics is not necessary. The objective of Phase I is to determine the feasibility of this approach and to develop a optimal configuration. The anticipated result is a bolt tension measurement technique which is easy to use, accurate, and applicable to all joint configurations and bolt types and that does not require bolt preparation or calibration on an individual basis.

Potential Commercial Applications: The result would be applicable to all equipment containing critical or remote bolt joints, such as aircraft and undersea vehicles. In addition, there are important applications in automated assembly and robotics.

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* **069** JSC
89-1-04.15-1980 NAS9-18318
A Whisker-Reinforced, High-Temperature Structural Insulation
Materials and Electrochemical Research
7960 S Kolb Road
Tucson, AZ 85706
J. C. Withers (602-574-1980)

New, unique high-temperature ceramic matrix composites with low thermal conductivity, high strength, and thermochemical stability to 2780°C are prerequisite to significant advances in heat-shield technology. Available heat shields, including carbon phenolics and the recently developed reusable surface insulation, have a temperature capability limited to about 1270°C. Both of these heat shield insulators have extremely low

mechanical properties. Some ceramic oxides have thermochemical stability to temperatures in the range of 2780°C. Such compositions coupled with selected advanced whisker reinforcements offer the potential for ceramic composites with ultra-high-temperature structural and insulative properties that have not heretofore been achieved. Sol-gel technology coupled with a plasma sintering technique produces a porous yet well-bonded composite that has very low thermal conductivity with good structural strength. This project will fabricate new and unique zirconia-matrix-based composites with whisker reinforcements and evaluate thermal and mechanical properties for the development of a load-bearing heat shield for use at 2780°C.

Potential Commercial Applications: A high-temperature structural insulation would have commercial applications as thermal barrier coatings in gas turbine engines, spark ignition and diesel engines, furnace insulation, etc.

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070 JSC
89-1-04.15-5301 NAS9-18301
Protective Coatings for Components Used In Space
Advanced Diversified Technology, Inc.
5965 Pacific Center Boulevard, Suite 715
San Diego, CA 92121
Charles Y. Lin (619-455-5301)

In low Earth orbit, surface materials of the space transportation system and space station are subjected to deleterious environmental factors. This project investigates two new inorganic oxide polymers (invented by the principal investigator) as protective coverings for components used in space. After application and curing, these polymers form covalent bonds to metal and non-metal surfaces. The final coatings are non-permeable to corrosive gases; resist oxidation, erosion, and high-temperatures; and they are relatively low in cost. In Phase I, various substrate coupons commonly used for components in the space industry will be coated with these polymers for preliminary testings of the surface properties. In Phase II work will further characterize these coatings and various means of surface applications by simulated and real environmental testing.

Potential Commercial Applications: Economical, versatile, and high quality protective coatings are needed in almost all industries with product lines ranging from common household products to high-tech components.

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071 JPL
89-1-04.16-4995 NAS7-1094
Atomic-Layer CVD of Yttrium-Barium-Cuprate Over a Low-Dielectric Substrate
APA Optics, Inc.
2950 N.E. 84th Lane
Blaine, MN 55434
M. Asif Khan (612-784-4995)

Atomic-layer chemical vapor deposition (CVD) will be used to apply high-Tc, YBaCuO layers over a composite $Al_xGa_{1-x}As/Al_xGa_{1-x}N$/sapphire substrate. The unique atomic layer process is expected to reduce the epitaxy temperature well below that required for conventional metallo-organic CVD and thus eliminate the need for a post-deposition anneal. The substrate stack is also unique. It has a dielectric constant much lower and thermal conductivity and mechanical strength much superior to GaAs. Utilizing the firm's work on high-T_c superconductor deposition and single crystal, multilayer $Al_xGa_{1-x}As/Al_xGa_{1-x}N$ depositions over sapphire substrates, the Phase I effort will lead to a multilayer stack well suited for fabrication of high-frequency, low-loss MMIC circuits with superconductor electrodes. The resulting films will be characterized for their superconducting transition temperatures. Phase II will focus on the fabrication of integrated MMIC devices.

Potential Commercial Applications: This project could yield several high-performance sensor and MMIC devices for applications in NASA and commercial communication systems.

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072 JPL
89-1-04.16-7646A NAS7-1090
In Situ Thallium Films by Laser Ablation
Superconductor Technologies, Inc.
460 Ward Drive, Suite F
Santa Barbara, CA 93111-2310
J. L. Nilsson (805-683-7646)

It is generally accepted that the best high-temperature superconducting films will be epitaxially grown on single crystal substrates using vapor-phase deposition techniques. The highest quality films of YBCuO have been produced using vapor-phase deposition, but the best films in the thallium system have been produced via post-deposition annealing. Preliminary experiments have demonstrated that it is possible to grow at least one phase of the thallium family (1122) on a single crystal substrate that is microwave compatible by laser ablation in the presence of active oxygen. This project addresses two problems facing the successful growth of thallium films via vapor deposition techniques. These films should have far superior properties to those films produced by post deposition annealing. Innovative techniques to control both oxygen activity and thallium volatility will be tested in Phase I to prove feasibility.

Potential Commercial Applications: Single crystal films are expected to exhibit much lower microwave loss and much lower surface resistance, making possible the commercialization of these materials in microwave components and subsystems.

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*** 073** LaRC
89-1-04.17-1167 NAS1-19012
High-Field, High-T_c Superconducting Magnets
Radiation Monitoring Devices, Inc.
44 Hunt Street
Watertown, MA 02172
Michael R. Squillante (617-926-1167)

The discovery of superconductivity at high temperatures (90 K) in copper-containing ceramics has resulted in the rapid acceleration of research directed toward producing and examining new compounds both to improve performance characteristics and to understand better the phenomenon. Realization of the potential commercial benefits of this new discovery depends as much on advances in production technology as on materials research. Many applications for high-T_c superconductors, including magnets, need large-area films and tapes. However, many of the processes for making superconductors are limited to expensive, small-scale, laboratory techniques. This project will investigate the use of a proven, low-cost process--chemical spray pyrolysis--to deposit large-area superconductor films. This innovative technique is versatile and should allow for rapid improvements in the electrical, magnetic, and mechanical properties. The feasibility of depositing large-area, high-quality films of $Tl_2Ca_2Ba_2Cu_3O_{10}$ superconductors using spray pyrolysis will be studied with the specific goal of developing a high-field super-conducting electromagnet.

Potential Commercial Applications: A practical fabrication process for high-T_c superconductors could enable usage for magnets, very-high-speed switching, microwave waveguides, homopolar generators, EMI shielding, and hybrid superconductor/semiconductor devices.

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*** 074** LeRC
89-1-04.17-2681 NAS3-25868
Novel Process for Thin-Film Growth of Yttrium-Barium-Cuprate
Advanced Technology Materials, Inc.
520-B Danbury Road
New Milford, CT 06776
Peter S. Kirlin (203-355-2681)

The ability to use high-T_c, superconducting devices in high-frequency communications depends on the development of a low- temperature deposition process with exacting control of stoichiometry and morphology. Metallo-organic chemical vapor deposition (MOCVD) can meet these needs; however, recent work by the company shows that films of YBaCuO and BiSrCaCuO grown by MOCVD at temperatures less than 800°C are amorphous mixtures of oxides, with a cauliflower-like morphology indicative of low-surface-mobility growth. Surface mobilities can be enhanced through the use of a plasma. At 600°C, a 50 eV oxygen ion beam oxidized BaF_2 to BaO which suggests that plasma-enhanced chemical vapor deposition (PECVD) will effect growth of supercon-ducting thin films with the existing reagents at 600°C or below. Phase I will demonstrate the growth of in-situ superconducting thin films with PECVD. Phase II will focus on process optimization through the correlation of plasma properties with the high-temperature, super-conducting thin-film characteristics. This will allow a Phase III scale-up of the PECVD process to multi-wafer production.

Potential Commercial Applications: Applications are expected in the fabrication of passive, high-frequency devices which have the potential to enhance the bandwidth and range of NASA's next generation of deep-space and satellite communication systems.

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*** 075** LeRC
89-1-04.17-2694 NAS3-25869
Microwave-Compatible, High-T_c Superconducting Films on Sapphire Substrates
Neocera Associates, Inc.
100 Jersey Avenue, Building D, Box D-12
New Brunswick, NJ 08901
Roger Edwards (908-220-9149)

Among the potential applications of the new high-temperature ceramic superconductors are microwave devices for communications applications. Fabrication of such devices will require well-controlled techniques for preparing thin films of the materials on substrates having low microwave losses such as single-crystal alumina (sapphire). The innovative feature of this project will be to form high-temperature superconductor films on sapphire with a buffer layer interposed between the substrate and film to alleviate interface problems such as chemical interactions and thermal expansion mismatch. To promote well-ordered crystal growth of the superconductor layer, the buffer layer must be deposited epitaxially on the substrate, and close crystal-lattice matching between the buffer material and substrate are required. Several materials--including ZrO_2, $LaGaO_3$ and $LaAlO_3$--will be investigated for their suitability as buffer layers, and double-layer buffers will also be considered as a means of satisfying the different requirements. The effort emphasizes the use of a single technique, pulsed laser deposition, for forming both the buffer layers and the superconductor films.

Potential Commercial Applications: Microwave device applications which could benefit from the availability of high-T_c films on sapphire substrates include passive components such as resonators, filters, and striplines and active detectors and mixers based on Josephson tunneling phenomena.

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076 LeRC
89-1-04.17-3422A NAS3-25876
Ultra-Rapid, Textured Growth of Yttrium-Barium-Cuprate Filaments for Composite HTSC Wire
CPS Superconductor Corp.
155 Fortune Boulevard
Milford, MA 01757
John W. Halloran (508-634-3422)

A process will be developed for manufacturing continuous, multi-filamentary HTSC wire with high critical current using an innovative, ultra-rapid, textured-growth process. This process is based on experiments

showing locally oriented growth of Y-123 by metastable congruent melting and solidification during two-second rapid anneals. This method will be developed for processing continuous Y-123 fibers for multi-filamentary composite wire.

Potential Commercial Applications: Applications for multi-filamentary HTSC wire could be in magnets, motors, bearings, and power transmission.

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077 MSFC
89-1-04.17-5634 NAS8-38464
Increasing Critical Current Densities in High-T_c Superconductors
Castle Technology Corp.
262 West Cummings Park
Woburn, MA 01801
J. Paul Pemsler *(Last Known Address)*

Recent excitement over advances in high-temperature superconductivity has been tempered by the difficult problems that need to be solved before practical use can be made of these discoveries. Foremost among these problems, and the one which is addressed in this project, is the ability to achieve adequate current densities in moderate magnetic fields in the high-T_c materials. The major source of the "weak-link" behavior in polycrystalline materials is poor inter-grain contacts. This project seeks largely eliminate these weak-link, inter-grain contacts by producing a novel morphology wherein the grain-boundary composition is modified by the presence of nanometer-thick films of silver.

Potential Commercial Applications: Success in improving critical current densities for high-T_c superconductors would enhance their use in smaller, faster computers, magnetic levitation for transportation, improved magnetohydrodynamic energy generators, large scale (>1000 hp) electric motors, fusion reactors, medical imaging systems, and electric power transmis-sion.

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* **078** JSC
89-1-04.18-3260A NAS9-18315
Production of Oxygen by Electrolysis of Lunar Soil in Molten Salt
EMEC Consultants
R.D. 3, Roundtop Road
Export, PA 15632
Rudolf Keller (412-325-3260)

Costs for missions in space may be reduced significantly by utilizing lunar resources, particularly oxygen. This project will investigate electrolytic production of oxygen from molten salt. This process would use lunar soil with minimum or no beneficiation and not produce any waste. A metal alloy would be obtained as a useful byproduct. Trouble-free cathodic deposition, recovery of the metal components, minimal electrolyte losses, and sufficient stability of anodes are major prerequisites for the process to be viable. In Phase I, the cathodic deposition of the metal components of lunar soil will be studied. Experimentation will be conducted with Carlton Peak anorthosite and University of Minnesota MLS-1 to simulate lunar soil. While mainly carbon anodes will be employed in Phase I, electrolysis with oxygen-evolving anodes would be studied in Phase II, introducing a wide range of feed material compositions. Phase II will also include work on the recovery of lithium from the cathode product.

Potential Commercial Applications: Potential terrestrial spin-offs are the technology for the processing of fly-ash and unconventional ores.

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079 JSC
89-1-04.18-7500 NAS9-18312
Feasibility Study for Lunar Cement Production
Construction Technology Laboratories
5420 Old Orchard Road
Skokie, IL 60077
T. D. Lin (312-965-7500)

Man-made bases on the moon will require structures capable of resisting a differential pressure of one atmosphere as well as solar wind and radiation. Small structures may be prefabricated on Earth and transported to the moon. However, large structures must be constructed using lunar materials. A potential material for such construction is concrete made from lunar materials. Concrete is basically a mixture of cement, water, and aggregate. It has been shown that lunar soils can be used as aggregate and that oxygen to produce water can be extracted from lunar ilmenite. The only terrestrial substance needed for making concrete on the moon is hydrogen, of which about 5 oz. is required for 100 lbs. concrete. Possible methods for producing cement materials from lunar anorthite and other lunar materials such as glasses will be explored. Use of ultra-high-heat-flux, solar-energy-concentrator optics recently developed at the University of Chicago will be considered as a possible mechanism to provide heat for pyro-processing the candidate lunar materials.

Potential Commercial Applications: Possible spin-offs could be the replacement of current rotary kilns with the ultra-high flux solar energy concentrators to save fossil fuel and minimize air pollution.

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05: Teleoperators and Robotics

* **080** LaRC
89-1-05.01-9200 NAS1-19020
Wavelength-Diplexed, Fiber-Coupled, Coherent Laser Radar Measurement System
Digital Signal Corporation
8003 Forbes Place
Springfield, VA 22151
Anthony R. Slotwinski (703-321-9200)

Fiber-coupled proximity sensors with high speed and accuracy are needed for robotic end effectors and automated inspection and quality control. This project

will demonstrate a novel, robust, integrated sensor concept with multiple sensor capability. Fiber-optic sensors have geometric flexibility. Phase-modulated, interferometric-type sensors have high sensitivity as well. However, due to the sensitivity of conventional, single-mode fibers to environmental perturbations, polarization fading and drift are limiting factors. The Phase I effort is to design and demonstrate a wavelength-diplexed, fiber-optic-measurement system that utilizes both a multi-mode laser radar and a frequency-modulated laser radar in a coherent detection configuration that eliminates the problem of environmental perturbations. The proposed design has the flexibility to multiplex a number of miniature sensors mounted on robotic end effectors and tools to measure proximity, tactile pressure (touch), force, and torque.

Potential Commercial Applications: Potential applications would be in factory automation, telerobotics, machine tools, robotic sensors, process control, and non-contact sensing and gauging.

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081 LaRC
89-1-05.01-9355 NAS1-19005
Identifying, Locating, and Tracking Objects by Detecting Pre-Affixed Colored Targets
American Innovision, Inc.
9581 Ridgehaven Court
San Diego, CA 92123-1624
Jose R. Torre-Bueno (619-560-9355)

The sensing and perception requirements for NASA's automated operations are addressed in this project with a novel combination of tracking targets and algorithms that would simultaneously identify, locate, and track many objects viewed by a pair of color video cameras. The key innovation is the use of pre-affixed, multi-colored tracking targets and a hardware preprocessor for rapidly identifying them under variable illumination. This system offers advantages in capacity, speed, ease of programming, and cost. Hundreds of thousands of objects could be identified, and dozens tracked simultaneously. Locations and orientations of dozens of identified objects could be determined every 60th of a second. The system design is inherently self-teaching and requires only two low-cost, color cameras and one board built with off-the-shelf LSI and VLSI components. The anticipated positional accuracy is plus or minus several millimeters at a range of 10 meters. In Phase I, the company will build and test a prototype which has all the capabilities of the final system except real-time tracking.

Potential Commercial Applications: Applications would be found in numerous robotic vision systems for aerospace and industrial applications.

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*** 082** GSFC
89-1-05.03-0559B NAS5-30853
High-Performance, Multi-Axis Strain Sensing
Sarcos Research Corporation
261 East 300 South, Suite 150
Salt Lake City, UT 84111
Ian D. McCammon (801-531-0560)

Internal sensing and control of adaptive mechanical structures such as robots, teleoperators, and large space structures require strain measurement at nodes within the structure. These measurements have usually been accomplished using uniaxial strain gauges. However, when several strains must be measured at a single point, elaborate compensation approaches must be devised in order to determine accurately their magnitudes. The resulting transducers are large, costly, and unreliable. The goal of this project is the development of miniature, reliable, low-cost, six-axis load cells for measuring strains at structural nodes. Based on the analysis of an existing prototype, this project will address two specific aspects of the device: reliability and packaging. The Phase I effort will analyze device structure and electrical performance; reliability and performance of the electronics; and packaging requirements for reliability and low cost.

Potential Commercial Applications: This technology should lead to substantial advancements in the safety and performance of mechanical systems and structures, particularly in robotics, airframe strain analysis, and spacecraft and space structure monitoring.

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*** 083** GSFC
89-1-05.03-1522 NAS5-30872
Integrated Ergonomic System Software Development
Photon Research Associates, Inc.
9393 Towne Centre Drive, Suite 200
San Diego, CA 92121
James D. Turner (617-354-1522)

NASA's need for modeling astronauts during EVA and space construction activities requires the development of an integrated simulation capability. Since astronauts wear restrictive clothing, they must be modeled in a way that reflects their loss of normal range performance. An integrated simulation environment provides the means for modifying the task structure and work space environment so as to reduce the work load in a manner consistent with the individual's physical capabilities. The basic human-machine dynamics prediction capability must be able to analyze complex, rigid and flexible machines as well as dealing with human models ranging from simple stick structures through complete myocybernetic musculoskeletal models. A two level approach will be utilized for addressing functional unit-to-tasks and high-level anatomical-to-functional performance assessments.

Potential Commercial Applications: Several direct spin-offs are possible in rehabilitation, design of active and neural prosthetics, sports performance, and medicine.

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084 GSFC
89-1-05.03-40071 NAS5-30807
Telerobot Control Interface Based on Constraints
Intelligent Automation, Inc.
1370 Piccard Drive, Suite 210
Rockville, MD 20850
Leonard S. Haynes (301-424-4007)

Fine manipulation via teleoperation is time consuming and unreliable because of limited sensory feedback. A preferred approach would be to use prestored, off-line programs that would allow the robot to perform the tasks autonomously under the supervision of an operator. This would result in the safety and flexibility of a teleoperated system but with the efficiency of an autonomous robot. This project will employ the firm's formal approach for specifying the manipulation tasks steps that are required to develop software for adaptively controlling and monitoring robotic operations. Fifteen primitive operations have been defined based on the reduction in the degrees of freedom that occurs when components are assembled and manipulated. These primitives appear to define elegantly and completely the fine manipulation required for simple assembly tasks. Each of the primitives has an execution strategy and a set of recovery algorithms in the event the operation fails. This project will expand the work already done and demonstrate its applicability to teleoperation.

Potential Commercial Applications: This system would be applicable to off-line robot programming, would define complex manipulation tasks based on a small number of primitives, and would allow an operator to understand and alter pre-coded, fine-manipulation algorithms.

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*** 085** JSC
89-1-05.04-3909 NAS9-18307
A Robot Wrist Using New Mechanism Technology Invented for Whole-Arm Manipulation
Barrett Technology, Inc.
545 Concord Avenue
Cambridge, MA 02138-1105
William T. Townsend (617-868-7730)

The project will adapt mechanical transmission technologies invented at MIT to a modular wrist for arm and hand grasping consistent with whole-arm manipulation. The resulting wrist design will feature a cabled differential driven by remotely located motors via high-speed transmissions. The differential will allow access through the wrist for hand actuation. The wrist will be built integrally with the forearm for modular connection to the MIT Whole-Arm Manipulator and Robotics Research Arm (both are being evaluated by NASA/JSC for EVA Helper and EVA Retriever programs) or in another modular arm. Phase I will develop a design concept including wrist performance specifications, determine the kinematics, and identify key actuation-component mechanisms. In Phase II, the required component mechanisms would be developed and integrated into a working wrist prototype. The anticipated result is a modular wrist for the integration of robotic arms and hands in support of NASA's EVA robotic programs.

Potential Commercial Applications: This wrist would enable the grasping of objects ranging in size from submillimeters to several meters. The cabled differentials and high-speed drives could apply to mechanisms such as copying machines, printers, and cassette players

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*** 086** JSC
89-1-05.04-5042 NAS9-18308
Glove Controller with Force and Tactile Feedback for Dexterous Robotic Hands
Begej Corporation
5 Claret Ash Road
Littleton, CO 80127
Stefan Begej (303-973-5042)

This project addresses the control of robotic hands in space applications for remote performance of highly dexterous tasks. The objectives are to establish the feasibility of developing a master glove controller that provides both force and fingertip tactile feedback and to determine the extent to which tactile feedback improves dexterous task performance. The work includes development of an electrically-driven, three-fingered, exoskeletal glove controller; assembly of drivers and signal processors for fingertip-shaped tactile stimulator and sensor arrays, each containing 44 elements; and evaluation of the performance of the master-slave system while operating in a bilateral force and tactile control mode. The prototype glove controller will serve to guide the development of an advanced device in Phase II to include additional fingers, smaller glove size and weight, faster actuators, and higher density tactile stimulator arrays placed at the fingertips and other areas of the glove.

Potential Commercial Applications: Applications would be in high-value, remote work such as manufacture of semiconductors or pharmaceuticals, radioactive hot-cell operations, hazardous waste processing, and undersea operations.

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087 JSC
89-1-05.05-6900 NAS9-18310
An Expert Advisor for Failure Mode and Effects Analysis
Carnegie Group, Inc.
Five PPG Place
Pittsburgh, PA 15222
David A Hornig (412-642-6900)

Failure mode effects analysis (FMEA), used extensively in defense and aerospace projects, is currently performed either by hand or with software that only supports formatting and criticality propagation. This project investigates an expert systems advisor for FMEA generation that will apply domain-specific knowledge gained from experts and from analogous FMEAs of similar designs. The advisor will improve the

accuracy and completeness of the FMEA and reduce the time for its preparation. These factors will lead to its earlier use in the design cycle and result in more reliable designs for space systems. Feasibility of the advisor will be demonstrated by evaluating a prototype against three small-but-realistic design examples that will test the representation and reasoning mechanisms of the prototype. The long-range development strategy (Phase II and beyond) covers conventional tools for FMEA generation, integration of FMEA with other automated design tools, criticality analysis of redundant systems, and automatic diagnostic tools from FMEA studies.

Potential Commercial Applications: The advisor would be used by companies that produce products where reliability is a critical issue. Opportunities exist for consulting and for selling knowledge bases that cover FMEA generation for specific design domains.

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088 JPL
89-1-05.06-3729 NAS7-1096
A VLSI Three-Dimensional Processor for Advanced Robotic Manipulation
Dynamic Microsystems
475E Cannon Green Drive
Goleta, CA 93117
Yulan Wang (805-961-4974)

The digital control of robotic systems, an extremely numerically intensive problem, is important to the automation of manipulation tasks in space. Algorithms for solving these problems are most efficiently formulated using three-dimensional geometric computations (i.e., cross products, vector rotations, and homogeneous transformations). Joint work with the Center for Robotic Systems Microelectronics at the University of California at Santa Barbara has developed a unique processor architecture--the 3DP--that demonstrates superior performance for three-dimensional computations. This architecture has already been proven by a discrete-logic implementation. An object-oriented C++ compiler has already been written to support this unique design. This project integrates the 3DP into VLSI. A VLSI-3DP will provide a small, energy-efficient processor with the computational power to perform advanced manipulations in space.

Potential Commercial Applications: The VLSI-3DP will be incorporated into the firm's own controller products for advanced manipulation in manufacturing and automation. This chip will also be useful in other fields such as animation and three-dimensional modeling.

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* **089** JPL
89-1-05.06-3729A NAS7-1086
A Precise, Force-Controlled Robotic System
Dynamic Microsystems
475E Cannon Green Drive
Goleta, CA 93117
Yulan Wang (805-961-4974)

A robot capable of dexterous, force-controlled manipulation would allow the automation of delicate tasks in space, particularly during unmanned missions or extra-vehicular activities. Analytic proofs show that existing advanced control strategies should be capable of dexterous force control. The development of precise force controlled robots requires a mechanism able to execute the force commands and a control system that can satisfy the computational requirements of advanced force control algorithms. A new robot controller, the 3DP, developed by the firm offers the computational power needed for advanced robot control. By coupling this controller with a carefully designed, low-inertia, redundant mechanism, a precise, force-controllable robotic system will be developed. Phase I will demonstrate, through computer simulation and analysis, that the robotic system described can produce precise, force-controlled manipulations.

Potential Commercial Applications: A force-controllable robot opens commercial robotics to a completely new world of automation applications. A few examples are polishing material, valve assembly, cooperative moving of large delicate objects, and assisting in surgical operations.

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* **090** JPL
89-1-05.06-8500 NAS7-1074
Global-Local Environment Telerobotic Simulator
KMS Fusion, Inc.
P.O. Box 1567
Ann Arbor, MI 48106-1567
Frederick S. Schebor (313-769-8500)

Because the requirements for autonomous robots are far beyond the state-of-the-art in artificial intelligence and computer vision, NASA must use telerobotic systems to reduce the frequency of potentially unproductive and danger-ous extravehicular activities by space station astro-nauts. Past experience shows that teleoperation is demanding and requires the operator to maintain an accurate mental model of the local environment of the manipulator even in adverse lighting and sensory conditions. To simplify teleoperation, a global-local environment telerobotic simulator (GLETS) will be designed to simulate the remote manipulator and its local environment. It will update continually the simu-lated environment using remote sensors and display the simulated environment with rich visual and audio cues that can be easily interpreted by the operator. CAD/CAM will be used to establish databases for the simulated robot environment and robot descriptions. The simulator will provide a flexible software architecture that is easily modified and extended. It will adhere to the NASREM standard for telerobotic control to allow its easy integration into NASA's telerobotic program.

Potential Commercial Applications: A telerobotic simulator that could adapt to nearly any type of applications environment would provide a safe and

inexpensive training facility and facilitate configuring of robots, mission and contingency planning, and error recovery.

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*** 091** LeRC
89-1-05.07-2137 NAS3-25833
Brushless Motor Robotic Actuator Optimization
Unique Mobility, Inc.
3700 South Jason Street
Englewood, CO 80110
David W. Parish (303-761-2137)

A novel means of constructing a lightweight, brushless dc motor that operates with high efficiency, high power output, and low torque ripple has been invented by the firm. This motor can be configured for direct drive or be combined with a high-efficiency, high-rigidity, zero-backlash reducer, such as a cycloidal reducer, to provide an ideal actuator for teleoperators, robotic manipulators, or space mechanisms. This actuator would be an important component to allow such advanced manipulator control techniques as output decoupling of robot arm dynamics, remote center of compliance control, or disturbance decoupling of reaction forces and moments. The specific Phase I technical objective is to design an optimal electro-mechanical actuator for precise, incremental, motion control for teleoperated and robotic manipulators in an outer-space environment and to assess its merit with respect to other existing actuators for use in advanced control systems.

Potential Commercial Applications: A brushless, dc actuator featuring low torque-ripple, high power-density and high efficiency could be utilized for teleoperated robotic manipulators in a variety of industrial and space applications.

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*** 092** KSC
89-1-05.08-3200 NAS10-11659
Self-Contained, Deployable, Serpentine Truss for Prelaunch Access of Orbiter Payloads
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02154-1196
Ken Pasch (617-890-3200)

The self-contained, deployable, serpentine truss (SCDST), which would be deployed from a transportable tube, is an articulated, modular truss structure and control system capable of snake-like curvature and snaking along a desired trajectory. The system is controlled by an algorithm of linear computational complexity and is specifically designed to allow inspection and light tasks to be performed on payloads in the cargo bay of the space shuttle orbiter while on the launch pad. The proposed SCDST is a cost, time, and safety alternative to the present procedure in which technicians erect temporary scaffolding.

Potential Commercial Applications: Applications of the SCDST system are inspection and light tasks performed in cramped or uninhabitable quarters such as heat exchangers, boilers, storage vessels, etc.

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093 KSC
89-1-05.08-8988 NAS10-11658
Tortuous-Path Robot Transport
Transitions Research Corporation
15 Great Pasture Road
Danbury, CT 06810
J. F. Engelberger (203-798-8988)

This project investigates a built-up structure to transport a robot arm to its work site for spacecraft assembly, test, and maintenance. The robot includes a nested, limp member that can be extended and continuously rigidized in any angular orientation with respect to the robot. The robot would lock its "tail" to some structure before entering the obstructed work zone. Then the robot would proceed on its circuitous path supported by extending the rigidized tail to conform to the path that the robot travels. The robot arm reels in its tail to follow the reverse route. There would be no need for continuous articulation of a series of elements to maintain relative position within the tunnel. The robot arm would be "built" as a rigid support for the robot no matter what the path to the work site. Mechanical complexity for a universal solution would be greatly reduced. In Phase I, a variety of operating principles will be examined. Most promising is a flexible tube filled with fluidized particles that interlock upon fluid extraction.

Potential Commercial Applications: Applications would be in maintenance of nuclear power plants, ships, aircraft and space vehicles, etc., particularly where the environment is hazardous or where extensive disassembly would be necessary to permit human access to a work site.

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*** 094** MSFC
89-1-05.09-5959A NAS8-38443
Advanced Telerobotic Concepts Using Neural Networks
Accurate Automation Corporation
1548 Riverside Drive, Suite B
Chattanooga, TN 37406
Craig T. Harston (615-622-4642)

By applying neural network technology to telerobotics, this project will benefit from some of the advances that are being done for autonomous robots. These concepts will extend the capabilities of the human operator. The telerobotic controller will be taught using backward shaping to improve its speed of learning, and a capability for association-based, sensor-data fusion will be added. The controller will be adapted to have multiple joints controlled by hybrid neural networks. The project will see if the neural network can improve performance for minimum jerk and minimum torque criteria based upon the learning. These concepts should allow for control of multiple joints or degrees of freedom in the robotic problem.

Potential Commercial Applications: This project is applicable to various robotic, control, and assembly applications and could be applied to avionics and process control systems. It may provide a basis for long-term development of robust, effective autonomous and semi-autonomous systems.

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095 MSFC
89-1-05.09-6511 NAS8-38458
Active Detection and Tracking Sensor for Passive Targets
Computer Algorithm Development
2806 A Nueces
Austin, TX 78705
Richard E. Shultz (512-474-6511)

This project will demonstrate a superior, active, detection and tracking sensor, ADTS, by combining artificial intelligence software with a microcomputer, video camera, and image digitizing electronics. It will apply a novel object recognition algorithm being developed by the firm for the USAF. With a passive marker (high contrast symbol or target) affixed to an object, the ADTS will be able to detect and track the object's attitude and position in three dimensions and real time. The ADTS will be innovative because of its tolerance of clutter in the image and because of its speed. Project objectives are to develop programs that can detect edges, lines, and targets in real time on a microcomputer. The company will develop Ai-computer-vision algorithms and code for detection programs using two Macintosh II computers. Applications for the ADTS include terminal guidance of a telerobot for grasping or berthing any object to which a marker target is attached and guiding the Orbital Maneuvering Vehicle during autonomous docking.

Potential Commercial Applications: Some commercial uses would be package sorting for the Post Office, UPS, and Federal Express, sorting containers for trash recycling, and stowing and retrieving items in an automated warehouse.

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06: Computer Sciences and Applications

096 LaRC
89-1-06.01-2490 NAS1-19034
The LAFS Kernel File System
Galloway Research
795 Beaver Creek Way
San Jose, CA 95133
John R. Galloway, Jr. (408-259-2490)

Over the past 15 years improvements in the price and capacity of disk drives have roughly matched the dramatic gains made in processor speeds. However, raw input-output and seek rates of disks have improved far less, and the basic architecture of kernel file systems has remained essentially unchanged. The result is that today's high performance systems are often severely limited by file-system throughput. This project investigates a new kernel file-system architecture called LAFS which, through the use of a new addressing paradigm, offers higher performance and reliability and greater ease of use than current designs. Improvements are available for both multi-threaded diverse loads (e.g., file servers, timesharing, DBMS) and for single stream applications (e.g., computation intensive analysis, graphics). Phase I will result in a functional emulation of this system operating on a single drive hosted in a conventional workstation. Performance under various loads will be compared to the standard system. These results and the host system software and interfaces would be directly used in Phase II/III for a full scale prototype.

Potential Commercial Applications: The key innovation is architectural and may be expressed in a wide variety of implementations for incorporation into existing product lines. The firm intends to license LAFS technology to computer system vendors.

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*** 097** LaRC
89-1-06.01-8633 NAS1-19016
Parallel, Multilevel, Adaptive Methods for Flows in Transition
Colorado Research Development Corp.
1727 Conestoga Street
Boulder, CO 80301
Chaoqun Liu (303-441-2491)

The purpose of this project is to develop an accurate and highly efficient parallel algorithm based on asynchronous, multilevel, adaptive methods for computational fluid dynamic problems involving transition caused by canonical roughness elements. Boundary layer transition is extremely sensitive to the presence and nature of roughness elements, but very little in known either experimentally or numerically about the precise nature of this relationship. The ultimate goal of this project is to develop effective computational tools for numerical analysis of these physical processes. The Phase I project will develop a prototype method for two-dimensional and three-dimensional, steady, incompressible flow in a channel. The approach will involve the development of the asynchronous, fast, adaptive, composite-grid method for such problems on the INTEL iPSC/2 using several different roughness elements, hemisphere, sphere, and cylinder.

Potential Commercial Applications: This project should enable parallel computer simulation of steady-state and time-dependent simulation of three-dimensional flows in transition involving canonical roughness elements.

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*** 098** GSFC
89-1-06.02-3370 NAS5-30848
CASE Visualization System
Software Productivity Solutions, Inc.
122 North Fourth Avenue
Indialantic, FL 32903
Andres Rudmik (407-984-3370)

In order to improve computer-aided software engineering (CASE) tools, this project applies a constraint-based, object-oriented paradigm to provide user-tailorable graphic visualizations. The company has applied this paradigm with considerable success to the modeling of complex object and process structures. The integration of the CASE visualization system with the firm's object management system will provide a powerful, tailorable CASE framework. These combined capabili-ties will allow users to define new methods, supply the automation to support these methods, and provide the graphic renderings through which objects are manipu-lated. The objective of this project is to provide a visualization system that will allow users to adapt CASE tools to match the needs of large complex software development projects.

Potential Commercial Applications: Commercialization may proceed by development of new or customized CASE tools or by licensing the CASE framework technology to major corporations and CASE vendors.

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* **099** GSFC
89-1-06.02-8211 NAS5-30871
Three-Dimensional, Solid-State, Multi-Port Memory System
Irvine Sensors Corporation
3001 Redhill Avenue, Bldg 3 #208
Costa Mesa, CA 92626
David E. Ludwig (714-549-8211)

A three-dimensional packaging technique will be applied to develop a solid-state, multi-port, high-speed, high-density memory system for spaceborne applications utilizing multiple data recording instruments. The system configuration will be as generic as possible. Since the memory system is solid state and contains no moving parts, it can withstand severe environments. It can also be configured with different, integrated-circuit memory technologies (SRAM, DRAM, EEPROM, ferroelectric) to best fit the specific application requirements. For example, a 64-megabyte mass memory based upon 256-kilobyte, radiation-hardened SRAM ICs would occupy less than 4 cubic inches. Using more advanced 1 megabit ICs, it will be possible to package a terabit of data into less than one cubic foot. The innovation is to replace optical recorders with this technology. During Phase I, the upper limits on size, bandwidth, and radiation resistance will be explored, and a low-risk Phase II demonstration unit configured. In Phase II, a high-density memory design suitable for near-term space use would be demonstrated.

Potential Commercial Applications: Applications are foreseen in supercomputers, mainframe computers, engineering workstations, spaceborne and airborne computers, and neural networks.

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100 LaRC
89-1-06.03-2020 NAS1-19008
Formal Verification of C with Unix
Odyssey Research Associates, Inc.
301-A Harris B. Dates Drive
Ithaca, NY 14850-1313
Douglas N. Hoover (607-277-2020)

An automated, formal verification system for programs written in the C programming language is the objective of this project. This system will support verification of programs that include Unix system calls, including those which make possible concurrent execution such as fork and pipe. It will also support verification of programs that do floating point arithmetic. The verifier will be based on an operational semantics which is powerful, easy to understand, and easy to use. Verifying a program with this system will he similar to symbolic execution. The system will be easy enough to use that it can be a routine debugging tool. The system will be based on the Ariel prototype C verification system developed at the company. The work of this project is to support full C including input-output. It must also develop and implement semantics for Unix system calls including those for concurrent programming.

Potential Commercial Applications: The system could be used commercially to verify critical software.

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101 ARC
89-1-06.04-0885 NAS2-13175
Site-Specific, Air-Traffic-Control Training Simulator with Speech Input and Output
Speech Systems, Inc.
18356 Oxnard Street
Tarzana, CA 91356
Philip C. Shinn (818-881-0885)

The goal of this project is to develop a site-specific, functional, prototype, air-traffic-control (ATC) training simulator. The system will support speaker-independent, continuous speech recognition for input of trainee commands and real-speech output of pseudo-pilot responses, allowing a trainee to use the system without other personnel. Training ATC staff is an expert, labor-intensive activity which may be improved through a sophisticated simulation of the ATC environment. The simulator can also be used to determine the feasibility of proposed changes in ATC procedures. This project will integrate the firm's expertise in automated speech recognition with that of a company which produces an ATC simulator in an effort to produce a practical site-specific demonstration.

Potential Commercial Applications: Applications would be in training for site-specific, air-traffic-control situations.

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*** 102** ARC
89-1-06.04-6871 NAS2-13174
Semi-Automatic Data Structure Selection
Kestrel Development Corporation
3260 Hillview Avenue
Palo Alto, CA 94304
Lee Blaine (415-493-6871)

This project addresses efficient prototyping of reliable software systems and deals with the four intertwined issues of reliability, reusability, coping with changes to the prototype, and generating efficient code from specifications. The company has developed a language for describing implementations of data structures and a data-type refinement environment (DTRE) for transforming to code the specifications annotated with implementation directives. In order to generate efficient code from specifications, the implementations of data structures must be carefully selected. Since fully automatic selection of implementations is beyond current technology, a semi-automatic system for data structure selection (DSS) will be developed. With this system, the user will supply some implementation directives and the system will determine the remainder. The DSS together with the DTRE will lead to critical, asymptotic improvements in the efficiency of rapid prototypes based on executable specifications. Just as critical is the increase in reliability that comes from automating the derivation of efficient code from specifications.

Potential Commercial Applications: DTRE is being considered for a commercial software development environment based on executable specifications and program synthesis. DSS combined with DTRE could be applied for generation of early, reasonably efficient prototypes in requirements analysis and as a design and coding tool.

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*** 103** ARC
89-1-06.04-8265 NAS2-13161
Knowledge-Based, Aerospace Program-Management Decision-Support System
ISX Corporation
501 Marin Street, Suite 214
Thousand Oaks, CA 91360
David Rosenberg (805-495-8265)

This effort will develop an associate structure for the organization and specification of knowledge related to program management decision support. Solution of the problems in associate systems requires progress in areas of software architecture, representational components, and development methodology. In the past, applications have been built using AI-shell tools that provide collections of low-level knowledge representation and inference capabilities. This effort will develop of a set of high-level, yet domain-independent, knowledge-representation constructs and application mechanisms. The general capability will be applied to a manager's associate for space systems process modelling and management. Phase I targets the development of a core capability of advanced knowledge representation and knowledge application. Phase II would focus on extension of the core capabilities and generalization of an associate system development methodology to aid in translating domain knowledge into this target environment.

Potential Commercial Applications: Preliminary market research indicates a tremendous need for a knowledge-based, decision-support system for engineering managers. There is currently nothing like it on the market.

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*** 104** JSC
89-1-06.05-3370 NAS9-18334
Passive Knowledge Acquisition System
Software Productivity Solutions, Inc.
122 North Fourth Avenue
Indialantic, FL 32903
Vincent Kovarik (407-984-3370)

The development of knowledge-based systems currently requires the use of a knowledge engineer to translate and encode the knowledge extracted from an expert into the target representation and reasoning system. Although the goal of providing systems with which the expert can directly interact has been pursued for some time, current systems do not meet it. A major reason is that experts must shift the focus of their cognitive processing between the performance of the task to be captured and thinking about how to encode that process. This project will develop a passive knowledge acquisition system which unobtrusively monitors and records the expert's actions. Then, using a collection of elicitation and discovery heuristics, the system queries the expert regarding the rationale and decision process behind the actions. This approach will provide an expert knowledge elicitation system which behaves much the same as a human knowledge engineer.

Potential Commercial Applications: The results could apply to the insertion of the technology into NASA programs, to capturing tactical knowledge in the battlefield for the military, and to commercial applications such as medical diagnosis and financial analysis.

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*** 105** JSC
89-1-06.05-8522 NAS9-18335
Fuzzy-Clips Expert System
Togai Infralogic, Inc.
30 Corporate Park, Suite 107
Irvine, CA 92714
Masaki Togai (714-975-8522)

Fuzzy logic is the reasoning methodology that has grown out of a branch of formal mathematics known as fuzzy set theory. It has been used to handle uncertainty in rule-based software systems, where it is particularly effective in capturing qualitative aspects of human reasoning. Many applications using the fuzzy logic inference mechanism for ill-defined expert systems have been successfully demonstrated in Japan and Europe. In spite of its apparent potential, this unique method has not been extensively used in NASA applications. A general lack of confidence in the

use of this powerful technology stems from the lack of adequate tools to develop systems. This project should result in user-friendly, easy-to-use, expert-system shells with this new paradigm embedded in the existing expert system shell, CLIPS.

Potential Commercial Applications: This software tool can be effectively used to construct expert systems for vehicle and process control, pattern classification, financial decision making, sales prediction, industrial design, and psychology.

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106 JSC
89-1-06.05-9896 NAS9-18306
Knowledge Networks for Mission Planning and Flight Control
Associated Dynamics International
139 South Beverly Drive, Suite 220
Beverly Hills, CA 90212
Cleveland W. Donnelly (213-271-9896)

Mission planning and flight control involve the coordination of both conceptual and physical variables. The fuzzy cognitive map (FCM) framework will be investi-gated as a flexible architecture for coordinating these variables in real-time parallel systems. FCMs are adaptive knowledge networks for representing uncertain goal, policy, utility, causal, resource, and physical variables that interact in the mission planning and flight control process. They synthesize expert-system search tree and neural network technologies in a novel, expressive framework. FCM knowledge acquisition reduces to causal-policy picture drawing and improves, not degrades, with increasing numbers of experts. Their inferential dynamics resemble neural network computations. The FCM matrix structure allows each matrix column to be concurrently processed in parallel. Neural networks can estimate FCM variables, such as mission success rates, from historical and on-line data. Expert system meta-rules can govern the firing of different FCMs, and vice versa, in complex, hybrid systems. Fuzzy control subsystems can be activated in parallel by FCMs and can, in turn, activate embedded FCMs to different degrees.

Potential Commercial Applications: Hardware implementations of adaptive decision support systems would facilitate medical, economic, financial, legal, and business management decision processes.

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107 ARC
89-1-06.06-2748A NAS2-13165
Program Mapping Strategies for Multiprocessor Computers
Dataflow Computer Corp.
55 Wellesley Road
Belmont, MA 02178
Jack B. Dennis (617-484-8932)

The paradigm compiler implements a new technology for compiling programs for scientific computation in large-scale, multiprocessor computers. The technology is based on analysis of the source program into code blocks, each of which defines a data structure. Each such data structure is mapped into the collection of processing elements of the target computer so that the collection of mappings yields the best possible performance. This project will provide a user-friendly interface through which users may advise the compiler regarding mapping choices for each code block and implement means for estimating performance of the compiled code as a function of target machine parameters and mapping decisions. It will evaluate various mapping strategies for several significant application codes and demonstrate the compiling technology at Connection Machine user sites. The benefits will be easier development of efficient codes for multiprocessor computers and clearer expression for scientific computation through use of a functional programming language. Another benefit is that the user of the paradigm can experiment with several mapping choices without having to make any changes to the high-level source language program.

Potential Commercial Applications: The results of this project can simplify the construction of efficient programs for large-scale multiprocessor computers.

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*** 108** ARC
89-1-06.06-2985 NAS2-13164
Application of High-Performance Digital Video to Computer Storage
Demografx
10720 Hepburn Circle
Culver City, CA 90232
Gary Demos (213-837-2985)

This project adapts ways to utilize high-performance digital television equipment for high-performance storage of digital information. This equipment allows data transfer rates of between 10 megabytes/second and 120 megabytes/second. Storage in RAM is available up to a few gigabytes. Storage on disk systems is available up to 5 gigabytes. Storage on magnetic tape is available up to 100 gigabytes per reel or cassette. Phase I of this project will develop designs for hardware interfaces to this equipment and algorithms for software to support data coding and error correction. Phase I will also produce a system architecture design for using this equipment in several useful computer system configurations. The hardware interfaces would be designed for VME and Ultrabus backplanes.

Potential Commercial Applications: The results of this project could provide high data-transfer rate, high-volume, secondary data storage for supercomputers.

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109 ARC
89-1-06.06-6642 NAS2-13163
Advanced Optical Head Technology
Microwave Monolithics, Inc.
465 East Easy Street, Unit F
Simi Valley, CA 93065
Daniel R. Ch'en (805-584-6642)

The firm has, with private funds, developed a proprietary optical device for focusing laser beams down to sub-micron spots for optical disc and drum applications. These devices are characterized by milligram masses, high numerical aperture, diffraction-limited performance at full numerical aperture, and fault tolerance. They operate at wavelengths many times shorter than the wavelengths of current optical disc systems. Through the use of such a device, disc information capacity can be theoretically increased by a factor as high as 500, i.e., to an estimated 5624 gigabytes for a 30 cm disk. Without increase of disc rotation speed, a single such device increases the data transfer rate by more than a factor of 22. Their extremely low mass allows heads based upon arrays of these optical devices with all array elements simultaneously available for use. Additionally, several such heads can in principle read or write from a disc or drum simultaneously without mechanical or optical interference. Combining these two techniques, a further hundredfold increase in data transfer rates is theoretically possible.

Potential Commercial Applications: Initial applications are expected to be in large database management and supercomputer peripherals. Eventually the market for these devices should exceed the present market for magnetic hard disks.

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*** 110** ARC
89-1-06.06-7450 NAS2-13177
A High-Resolution Autostereoscopic Display
Dimension Technologies, Inc.
176 Anderson Avenue
Rochester, NY 14607
Jesse B. Eichenlaub (716-442-7450)

Innovative computer graphics techniques are needed for the visualization of complex, three-dimensional, fluid-flow phenomena. These are often difficult to interpret when displayed in perspective on a two-dimensional screen even when color, shading, and other monocular cues are used. A display that provides true depth perception to the user is necessary to interpret results. This project's goal is the development of a flat panel autostereoscopic (three-dimensional) display providing color, high resolution, and depth perspective imaging. It will enable several observers situated across a wide angle in front of the display to see the image without optical aids. The specific aim of Phase I will be the construction of a "breadboard" demonstration model of the basic optical illumination technique that will prove the concept. This model would establish the foundation for further development of a full prototype during phase II.

Potential Commercial Applications: Applications would be in telerobotics, CAD displays, laptop PCs, medical imaging, avionics displays, and simulation and entertainment displays.

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*** 111** JPL
89-1-06.07-7505 NAS7-1085
A Distributed, Object-Oriented, Data Facility for Local-Memory, Parallel Computers
MIMD Systems, Inc.
1301 Shoreway Road, Suite 430
Belmont, CA 94002
Robert E. Larson (415-595-7303)

Local-memory, parallel-processing computer systems offer the potential for higher levels of performance at costs far lower than permitted by current uniprocessor technology. However, the architectures of these parallel systems present difficult problems for both data access and data communication. The Arachnid system will be developed as a general solution to these problems. Arachnid would consist of an interconnected series of servers using object-oriented database technologies to provide a high-level facility that would reduce the mean time required to gain access to arbitrary data structures in a distributed system. Arachnid would interface to clients executing on the host and could also provide additional services including data integrity and concurrency control.

Potential Commercial Applications: Arachnid would enhance high-performance computation and data-intensive processing by addressing the problems associated with configuring data in a local-memory, parallel processor in response to processing loads. The system could also form the basis of a powerful object-oriented database manager.

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07: Information Systems and Data Handling

*** 112** LaRC
89-1-07.01-4429 NAS1-19116
A Programmable, Image-Data-Compression Subsystem for Workstations
Optivision, Inc.
4009 Miranda Avenue
Palo Alto, CA 94304
Paul Farrelle (916-756-4429)

This project will develop a programmable image-data-compression subsystem containing multiple DSP chips to provide high-speed compression of images. The subsystem will plug into an inexpensive workstation and provide an extremely flexible, general-purpose, image-compression station. It will be readily programmed to compress high-resolution, multi-spectral images of any size in lossless and lossy compression modes. It is intended to provide a set of different algorithms (lossless, DCT, DPCM, Laplacian pyramid coding) that would be suitable in a wide range of applications. This cost-effective approach will allow the same capabilities to be provided to many scientists who can each investigate the particular properties of compression for their imaging requirements. This is desirable since each situation is somewhat different, and any compression system that fails to retain the

features of interest in a given application will render the images unusable.

Potential Commercial Applications: The product of this project would apply to image communication for teleradiology, video conferencing, and surveillance and to image database applications including picture ID systems, digital mapping, real estate.

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113 GSFC
89-1-07.02-0094 NAS5-30869
HIRIS-Oriented Visualization Software System
Vexcel Corporation
2477 55th Street, #201
Boulder, CO 80301-5703
Wolfgang Kober (303-444-0094)

This project will develop a software system for conveniently and meaningfully visualizing large, multi-dimensional data sets such as those from the future HIRIS sensor for the Earth Observing System. The techniques for visualization will include volumetric rendering and band compression as well as image displays, contour plots, spectral curve plots, and scatter plots. In particular, the ability to manipulate and navigate conveniently through the data will be provided.

Potential Commercial Applications: The direct commercial applications of such visualization software will be the effective use of multi-spectral imagery for exploration of natural resources and environmental monitoring.

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*** 114** GSFC
89-1-07.02-4429 NAS5-30890
A Hybrid Simulation System for Image-Data Compression
Optivision, Inc.
4009 Miranda Ave
Palo Alto, CA 94304
Paul Farrelle (916-756-4429)

Future NASA missions will be severely limited without suitable data-compression algorithms to allow use of high-resolution and high-frame-rate sensors. This project will develop a hybrid simulation subsystem specifically designed for research in image-data compression. The system will contain multiple DSP chips and custom hardware modules interconnected to provide compression at (near) real-time, video processing rates. The subsystem will plug into an inexpensive workstation and provide an image-compression station that can be readily programmed to investigate different compression algorithms. This will provide the raw computing power needed to allow truly interactive subjective optimization of compression parameters.

Potential Commercial Applications: A flexible, near-real-time-image-data compression board for available workstations would be a low-cost approach for research in image-data compression.

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115 SSC
89-1-07.03-1127 NAS13-411
Application of Fractals to Smoothing over the Parameter Space
Technology International, Inc.
429 West Airline Highway, Suite S
Laplace, LA 70068
Abdo A. Husseiny (504-652-1127)

This project explores the use of fractal geometry for smoothing spatially oriented data sets over the parameter space. The implementation algorithm will be capable of spatial auto-correlation among random time samples distributed over a given geographical location. Iterative methods will be employed to develop a graphical computer code for use by NASA-SSC as a statistics tool in analysis of spatial patterns and spatial interaction processes. Data sets will involve remotely sensed data and ancillary maps. One objective of Phase I is the exploration of a fractal, iterative, recursive algorithm in smoothing over the parameter space and in image restoration and reconstruction. Another objective is the development of the logic for the fractal algorithm appropriate for the statistics of spatial patterns and spatial interaction processes.

Potential Commercial Applications: Commercial applications include rendering elevation maps and graphics of irregular objects for use by the aerospace and movie industries. The capability would be useful in digital terrain displays for robotic applications and in interpretation of geological maps.

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116 SSC
89-1-07.04-4000 NAS13-409
Improved Accessing of Digital Data Bases by Geographic Information Systems
Autometric, Inc.
5301 Shawnee Road
Alexandria, VA 22312-2312
Daniel K. Gordon (703-658-4000)

This project weds advanced optical technology and hardware with state-of-the-art data base management systems and geographic information systems. The principal goal of this project is to develop digital data-transfer and workstation technology needed to convert magnetic tape archives to optical disk. During Phase I, an assessment of future optical technology hardware will be made; a requirements definition performed; an optical database designed; an estimate made for archive conversion at the National Space Technology Laboratory (NSTL); and a plan for optical disk system integration at NSTL developed. This will lead to actual Phase II installation of hardware and software at NSTL.

Potential Commercial Applications: The integrated optical testbed developed under Phase II will provide an experience base from which optical engineering and database management services can be marketed to industry and government.

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117 SSC
89-1-07.04-6685 NAS13-410
Raster and Vector Data Integration, Interactive Edit and Analysis
Spatial Information Sciences, Inc.
Mississippi Tech Transfer Office
Stennis Space Center, MS 34529
Gregory T. Reinecke (703-430-6685)

The goal of this effort is to establish a capability to combine raster and vector data structures into a unified data set. This unification of data structures will allow for the simultaneous, interactive editing of combined geographical positions and data values and the restructuring of raster data sets into topological structures. This project will test and evaluate the efficiency of automatic vector digitizing for the conversion of non-imaged spatial information. Spatial data, both imaged and non-imaged, are critical to the effective utilization of the newly developing geographic information systems (GIS) in resource management. Currently, imaged and non-imaged spatial data files cannot be integrated into a single, digital data base for analytical purposes. Once operational, this new technology will enhance the value of NASA'S satellite and remotely sensed data for use with GIS technology.

Potential Commercial Applications: Applications are in mapping, planning, and maintenance in areas of land use, communications systems, transportation systems, environmental impact assessment, utilities, military logistics, and resource management.

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118 GSFC
89-1-07.05-8181 NAS5-30847
Wideband, Multi-Channel, Acousto-Optic Spectrometer for Radio Astronomy Applications
Photonic Systems, Inc.
1900 South Harbor City Boulevard
Melbourne, FL 32901-2625
Dennis R. Pape (407-984-8181)

A compact, rugged, four-channel, acousto-optic spectrometer for processing radio astronomy signals will be developed. It will employ a multi-channel Bragg cell. This cell utilizes a special acoustic mode in gallium phosphide that allows multiple channels to be fabricated on a single substrate while maintaining at least 40 dB isolation between adjacent channels throughout the optical aperture. This new cell uses a self-collimating acoustic mode as well as apodized electrodes to minimize channel-to-channel crosstalk. The system will have a bandwidth of 1 GHz and a frequency resolution of 1 MHz. During Phase I, the multi-channel Bragg cell will be designed with rigorous crosstalk and thermal modeling to assure adequate performance in the spectrometer system. Optical and electronic components will be specified and evaluated, and an optical and opto-mechanical design completed with attention to long-term stability.

Potential Commercial Applications: Multi-element sensors are used in many industrial applications particularly in manufacturing and testing.

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119 LaRC
89-1-07.06-1188 NAS1-19030
Visible, Semiconductor Diode Lasers Grown by Hydride Vapor-Phase Epitaxy
Epitaxx, Inc.
3490 US Route One
Princeton, NJ 08540
Donald E. Ackley (609-452-1188)

Visible, semiconductor diode lasers are of interest for optical recording having increased densities and direct read-after-write applications. Available devices based on InGaP/InGaAlP heterostructures operate at wave-lengths of 0.67 μm; these cannot be easily reduced due to the need to incorporate aluminum into the active layers. An alternate approach of InGaP lattice-matched and strained layers grown by hydride vapor-phase epitaxy (VPE) on a GaAsP substrate with buffer layers may achieve operating wavelengths as short as 0.62 μm. Diode lasers grown by VPE with an GaAsP active layer and InGaP cladding have already demonstrated operating wavelengths as short as 0.68 μm. The use of InGaP, quantum-well, strained active layers and wide-gap, InGaP cladding layers, lattice-matched to GaAsP instead of GaAs, will allow reduction in operating wavelengths without adding aluminum to the active layers. These structures should provide an attractive alternative to InGaP/InGaAlP devices for visible laser structures.

Potential Commercial Applications: Solid-state, visible (0.62 μm) lasers could replace gas lasers in optical scanning and recording and enable new applications such as projection displays and character recognition systems.

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120 GSFC
89-1-07.07-3327 NAS5-30845
A Neural-Network, Dynamic Sequencer for Distributed Mission Planning and Control
General Purpose Machines Laboratory
16 Dickens Court
Irvine, CA 92715
Jurn Sun Leung (715-856-3327)

Scheduling of tasks for a future space mission under joint management by distributed control centers responsible for different components of the mission objective will be faced with different priorities, release dates, deadlines, interdependencies, and even conflicting demands on instruments, communication channels, and expendable resources. This project investigates a neural-network-based sequencer for the generation and continuous optimization of task schedules which, taking into account resource constraints, internal states, and external dynamics, balances the requirements of distributed control centers. The central innovation of this dynamic sequencer is an optimizing scheduling loop. The heart of this loop is a modified

Hopfield network whose many-termed energy function is constructed to reflect task priority, processing expenditure (time and resources), communication requirements, resource constraints, and time dependencies.

Potential Commercial Applications: An optimizing planner is a key element in manufacturing systems such as just-in-time manufacturing and factory automation for improved productivity.

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*** 121** GSFC
89-1-07.08-1745 NAS5-30840
A Distributed, Object-Type Management System for Heterogeneous Environments
REI Systems
P.O. Box 9183
McLean, VA 22102-0183
Veer V. Bhartiya (703-281-1745)

The innovation described here is the development of a distributed object type management system (DOTS) kernel that provides an integrated, uniform, and extensible framework for storage, retrieval, and update of heterogeneous objects. The DOTS approach provides a uniform framework to integrate heterogeneous objects of diverse forms such as text, structured data, and image in a distributed environment. It enables both of data and applications and/or functions to be integrated without modifying existing systems. It allows new systems to be developed and integrated easily by emphasizing the reusability of existing systems. In Phase I, a methodology to represent heterogeneous information systems using the object-type abstraction will be developed and evaluated by applying it to selected NASA systems. High-level design specifications for the DOTS kernel will also be developed in Phase I. The thrust of Phase II would be to design DOTS in detail and demonstrate it for selected NASA data systems.

Potential Commercial Applications: DOTS is applicable to organizations in the commercial and federal sectors many of which face problems in managing heterogeneous, distributed data.

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*** 122** JPL
89-1-07.09-8659 NAS7-1077
Ultra-Dense Magneto-Resistive Mass Memory
Nonvolatile Electronics, Inc.
5805 Amy Drive
Edina, MN 55436
James M. Daughton (612-920-8659)

The goal of this project is an ultra-dense magneto-resistive mass memory with an access time of a few microseconds and 100 megabytes/second data rates. It will be highly reliable due to the inherent reliability of magnetic storage with no moving parts. This mass memory requires no standby power and can be radiation hardened. The conceptual design will utilize the magnetoresistive random access memory (MRAM) technology conceived by two of the investigators and developed for space application at Honeywell. The conceptual design effort for a MRAM mass memory will include verification testing of memory densities in excess of 10^6 bit/cm^2; design and simulation of all circuit blocks; a floor plan for circuits; and the thermal, electrical power, and data bus analysis and density calculations for the integrated system . At the conclusion of the Phase I, all preliminary work for the start of a mass-memory system development will be completed.

Potential Commercial Applications: All computers from personal computers and work stations through large mainframes and supercomputers are becoming performance limited due to latency of disks. This technology would improve access time by a factor of 1000 while retaining nonvolatility.

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08: Instrumentation and Sensors

123 JPL
89-1-08.01-1188 NAS7-1087
A 128 X 128 Element, Indium-Gallium-Arsenide, IR Detector Array at 300 K
Epitaxx, Inc.
3490 US Route One
Princeton, NJ 08540
Gregory H. Olsen (609-452-1188)

A two-dimensional, indium-gallium-arsenide detector array of unprecedented size (128 x 128 elements) will be developed for room-temperature operation between 1.0 and 2.5 microns. An innovative, hydride vapor-phase epitaxy crystal-growth method and fiber-optic probing technique to measure quantum efficiency at the wafer level will be applied. Phase I will deliver 30 x 30 microns pixels (spaced 50 X 50 microns) of conventional $In_{.53}Ga_{.47}As$ detectors (for 1.0-to-1.7 microns) on a two-inch-diameter InP substrate together with probe data. Performance goals are an 80-percent QE (1.3 microns) and a 300K dark-current (-5V) density below 1 x 10^{-6} amp/cm^2. In the same pixel geometry, detectors of $In_{.8}Ga_{.2}As/InAs_{.6}P_{.4}$ (for 1.0-to-2.5 microns sensitivity) on three-inch-diameter InP substrates would be developed in Phase II. Two working 128 x 128 detector arrays mounted on a two-dimensional Reticon multiplexer would also be delivered. Performance goals include one-percent pixel dropouts and 300K D* $\geq$ 3 x 10^{11} cm(Hz)$^{1/2}$/W at 2.5 microns.

Potential Commercial Applications: Applications would be in satellite imaging, remote sensing, LIDAR, windshear avoidance, and spectroscopy.

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124 JPL
89-1-08.01-2681 NAS7-1075
Novel, Mercury-Cadmium-Telluride Growth Process
Advanced Technology Materials, Inc.
520-B Danbury Road
New Milford, CT 06776
James D. Parsons (203-355-2681)

Mercury-cadmium-telluride (MCT) alloys are of major importance for non-cryogenically cooled, 1.0-to-16.0 microns IR-detector arrays, but their use has been slowed by the dearth of repeatable growth processes capable of producing high-quality films and devices with abrupt or controlled junctions. A new, unassisted, pyrolytic metal-organic chemical-vapor-deposition (MOCVD) approach will be developed to grow epitaxial $Hg_{1-x}Cd_xTe$ ($x \leq 1$) alloys with one percent composition and thickness uniformity over a large area. High mercury concentrations at 10 microns/hour growth rates and substrate temperatures below 300°C should be possible with this method. This approach will use a unique reagent system to enhance the growth process and incorporate a novel reactant-inlet port to increase the vapor pressure of mercury at the growth surface. Phase I will yield a reproducible, epitaxial MCT growth process and lay the foundation for MCT, IR-detector-photodiode manufacturing process development in Phase II.

Potential Commercial Applications: Applications are possible in space-based, airborne, and ground passive imaging systems including uses as diverse as satellite mapping, automobile avoidance, and fighter-aircraft early warning systems.

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*** 125** GSFC
89-1-08.02-3240 NAS5-30868
Diode-Pumped, Short-Pulse Laser for Ranging and Altimetry
Continuum
3150 Central Expressway
Santa Clara, CA 95051
Jean-Marc Heritier (408-727-3240)

To perform Earth atmosphere sensing and ranging from space, a laser must meet the following requirements: short pulse width (60 ps to 1 ns), high efficiency ($\geq$ 10 percent), and high reliability. Based on an improved, solid-state, diode-pumped technology, this project will investigate the feasibility of a short-pulse, all-solid-state laser. High efficiency should result from diode pumping, and its compact, almost-monolithic design should ensure high reliability. Phase I will demonstrate a short-cavity oscillator--single longitudinal-mode, single transverse-mode, Q-switched at up to 1 kHz--which would deliver $\geq$10 μJ per pulse with a minimum pulse duration of less than 1 ns, and $\geq$1 μJ per pulse with a pulse duration of about 100 ps after compression. A flashlamp-pumped, regenerative amplifier will be used to test the amplification of these pulses. In Phase II, the firm would build the compressor and develop an all solid-state, quasi-cw diode-pumped, regenerative amplifier that will amplify the pulses up to the milli-Joule level.

Potential Commercial Applications: This could apply to soft X-ray photolithography for the semiconductor industry and for space-based or airborne experiments such as ranging, altimetry, bathimetry, and LIDAR.

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126 GSFC
89-1-08.02-7001 NAS5-30846
Cloud-Top Radiometer
Space Instruments, Inc.
4403 Manchester Avenue, Suite 203
Encinitas, CA 92024
James W. Hoffman (619-944-7001)

The cloud-top radiometer (CTR) is a new instrument that can monitor the altitude of cloud tops at a high repetition rate as an indication of potential storm activity. The CTR utilizes the oxygen A-band technique but incorporates a CCD area-detector array in a staring mode to achieve long dwell times and high sensitivity. This allows a small, lightweight instrument operating at ambient temperature to perform accurate altitude measurements without complicated scan mechanisms and cryogenic systems. The staring CTR also obtains high-resolution, cloud-top images for global, cloud monitoring and modeling programs. The CTR contains a stabilization mirror that permits making bi-directional reflectance measurements of the same cloud at multiple angles and stereo images of the clouds to be obtained for a correlating set of cloud-top altitude values. After the feasibility study and conceptual design of Phase I, a complete working breadboard model that could be flown on a Get-Away-Special aboard the STS would be built in Phase II.

Potential Commercial Applications: A small, low-cost cloud and severe-storm monitor would be adaptable to a variety of airborne and satellite platforms including geo-synchronous weather satellites.

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127 GSFC
89-1-08.02-7518A NAS5-30849
A Stochastic Rain Model and Its Application in Rain-Rate Estimation
Interdisciplinary Science Applications
3 Rollins Court
Rockville, MD 20852
Z. H. Karni (301-468-8912)

Reliable rainfall data is an important parameter in models used for weather prediction. It is also of concern to environmentalists studying the effect of acid rain and for water resources management. A stochastic model that captures the essence of rainfall processes in time and space will be investigated. Such a model will be used to determine the applicability and usefulness of the threshold method in rainfall estimation. The rainfall model will satisfy certain consistency requirements. It will consist of three parts; a stationary cloud field, a spatial random rain-field, and a moving window. Once the model is verified, the threshold method will be applied.

Potential Commercial Applications: Improved estimates of rainfall will be beneficial in areas such as agricultural planning and prediction, water resource management, flood control, etc. The rain-field model will be useful in hydrological modeling, flood prediction, and scavenging of pollutants in the troposphere.

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128 GSFC
89-1-08.02-9040 NAS5-30864
Very-Large-Scale-Integration Time-Interval Units
Schmidt Instruments, Inc.
2476 Bolsover Suite 234
Houston, TX 77005
Howard K. Schmidt (713-660-8414)

A fully monolithic, time-interval unit (TIU) will be constructed. It will apply custom, very-large-scale-integration (VLSI) circuits that combine analog and digital sections for a pre-amplifier, discriminator, enable gate, and time-to-digital converter. This TIU will dramatically reduce the size, weight, and power consumption of space-based laser altimeters. Additional advantages of this approach are improved reliability and performance at reduced cost relative to printed circuit board (PCB) and hybrid alternatives. Phase I will concentrate on design and testing of individual and independent sub-sections of the TIU; these results will be combined in Phase II to produce a complete TIU chip optimized for use in flight-rated, range-finding systems. Based on their previous VLSI and PCB-level design experience, the firm expects better than one nanosecond resolution from the segmented VLSI test part from Phase I. Refined TIUs produced in Phases II and III should deliver 100 picosecond accuracy with conversion times less than 30 nanoseconds.

Potential Commercial Applications: Applications that may benefit from improved TIUs include laser altimetry, bathymetry, mass spectrometry, remote sensing, LIDAR, and electronic test equipment.

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129 SSC
89-1-08.03-1522 NAS13-406
Multispectral, Remote Sensing Using SPRITE Technology
Photon Research Associates, Inc.
1033 Massachusetts Avenue
Cambridge, MA 02138
James C. Fraser (617-354-1522)

For continuous spatial and spectral analysis of optical radiation, a new concept for a spectrometer that performs in either a serial-scan (pushbroom) or a staring mode to detect infrared radiation will be evaluated. It applies a new detector device known as a SPRITE (signal processing in the element), which offers increased integration time, increased resolution, and reduced electronic processing over current area-array spectrometer concepts. Developed for thermal imaging at 8 to 12 microns, SPRITE currently uses mercury-cadmium-telluride photoconductive material. Optical compounding of HgCdTe and alternative materials for implementing SPRITE technology may allow coverage of the spectral regime from 1.1 to 14 microns. Phase I will analyze the essential solid-state physics of the SPRITE detector, explore alternative SPRITE materials and spectral bands, develop design concepts for a staring and scanning spectrometer, and predict major performance characteristics such as bandwidth signal to noise, resolution, and readout rates.

Potential Commercial Applications: This concept would apply to an airborne or satellite-borne pushbroom optical sensor and in a variety of passive and active optical sensing applications including in-situ process monitoring of industrial chemical vapor processes.

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*** 130** LaRC
89-1-08.04-1802 NAS1-19007
Novel, Cobalt-Doped, Magnesium-Fluoride Lidar Aerosol Profiler
Schwartz Electro-Optics, Inc.
3404 N. Orange Blossom Trail
Orlando, FL 32804
M. Acharekar (407-298-1802)

A breadboard, eye-safe, continuously tunable, Co:MgF_2 LIDAR for measurements of vertical concentration profiles of atmospheric aerosols will be constructed. It will use a new, room-temperature, eye-safe laser based upon a proprietary Co:MgF_2 crystal that is currently the only tunable, room-temperature Co:MgF_2 laser on the market. This system will provide vertical concentration profiles of atmospheric aerosols and can also be used for atmospheric remote sensing of water vapor, HC_1, CH_4, and NO_2. A differential-absorption LIDAR (DIAL) system will be assembled using a continuously tunable, Co:MgF_2 laser; steering optics; a compact, receiving telescope; a cooled InSb detector; and a computer to record the DIAL signals and control and monitor the laser wavelength.

Potential Commercial Applications: An eye-safe, continuously tunable, Co:MgF_2 laser for LIDAR could have a large market for multiple systems in each urban area to provide vertical concentration profiles of the atmospheric aerosols and to identify chemical species.

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131 GSFC
89-1-08.05-3232 NAS5-30863
An Airborne, Laser-Depolarization, Imaging Sensor for Terrestrial Measurements
Ressler Associates, Inc.
14440 Cherry Lane Court, Suite 212
Laurel, MD 20707
Gerald M. Ressler (301-206-3232)

The goal of Phase I of this project is to develop a preliminary system design that demonstrates the feasibility of a pulsed-laser imaging sensor for measuring the depolarizing effects of materials and structures on the Earth's surface. In addition, Phase I will investigate data analysis and image processing techniques for presentation and interpretation of depolarization data and evaluate the performance of typical, commer-

cially available, CCD cameras. Phase II would see the development and fabrication of a final design calibrated in the laboratory and then flown aboard a helicopter or aircraft. The data acquired during the Phase II flights would be used to evaluate the system's performance.

Potential Commercial Applications: Applications would be in remote detection of oil spills, crop and land resource management, geological and man-made feature characterization and identification.

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132 GSFC
89-1-08.06-0600 NAS5-30851
Single, Longitudinal-Mode, Alexandrite Lidar Transmitter
Light Age, Inc.
6 Powder Horn Dr.
Warren, NJ 07060
Donald F. Heller (201-563-0600)

A broadly tunable, narrow-band, frequency-stabilized, pulsed, alexandrite lidar transmitter will be developed for airborne and spaceborne missions. This laser transmitter will provide near transform-limited output pulses across the 760-to-770 nanometer spectral region. The approach is based on development of an actively stabilized, diode-laser, injection-locked, alexandrite ring laser. The Phase I feasibility investigation includes the design, fabrication, testing, and optimization of a testbed laser prototype. This effort will resolve the most critical performance issues and will permit the more extensive development of a lidar transmitter meeting all NASA requirements, including scaling to higher power and pulse energy, in Phase II.

Potential Commercial Applications: Direct commercial applications are possible in the fields of spectroscopy and photochemistry and in remote sensing. The company commercializes and markets new laser technologies for scientific and medical applications.

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*** 133** GSFC
89-1-08.06-4161 NAS5-30857
Systems for Continuous Tuning and Single-Mode Operation of Solid-State Lasers
Science & Engineering Services, Inc.
17 Serpentine Ct.
Silver Spring, MD 20904
Hyo Sang Lee (301-236-4161)

A tunable, narrow-band (≈ 0.001 cm^{-1}), stable (≈ 0.0005 cm^{-1}) alexandrite laser will be produced by injection seeding the laser oscillator with a stable, tunable diode laser. The diode laser will be precisely tuned and controlled by using a digital wavemeter and feedback mechanism. A large array detector and specific algorithm will process the wavemeter output which, together with a stable frequency reference, will achieve the required accuracy. This system will use a commercially available alexandrite laser in a ring-laser configuration for injection seeding. The diode laser beam will be injected through an optical isolator into the ring in the direction opposite to that of the laser output. The length of the laser resonator cavity will be precisely controlled dynamically with an active element to match the resonator mode-frequency with the injection-seeding frequency. True single-longitudinal-mode operation will be achieved by using a high-resolution wavemeter interfaced with the active cavity element of the laser resonator as the feedback element.

Potential Commercial Applications: Applications are possible in lidar profiling of atmospheric temperature and trace-gas concentrations and in chemical processing and reaction dynamics research, heterodyne laser radars, communications, hydrocarbon detection, and petroleum exploration.

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*** 134** LaRC
89-1-08.07-2299 NAS1-19003
Lasers Optimized for Pumping Titanium-Alumina Lasers
Schwartz Electro-Optics, Inc.
45 Winthrop Street
Concord, MA 01742
Glen A. Rines (508-371-2299)

The goal of this project is to develop pump lasers for the single-frequency, high-energy, Ti:Al_2O_3, lidar transmitter currently under development for NASA Langley Research Center. The master oscillator requires a cw (or quasi-cw) pump laser with an output of one to two Watts. The gain-switched, high-energy oscillator requires a pulsed, pump laser at about two Joules per pulse with a 200-to-500 nanosecond pulsewidth. The pulsed pump laser will use a graded-reflectivity-mirror unstable resonator, high-gain Nd:YLF laser material, a compact Faraday isolator, and the stable-relaxation-oscillation laser concept. The ideal pump for a space-based Ti:Al_2O_3 master oscillator is a diode-laser-pumped, cw, Nd-laser with efficient, intracavity-second-harmonic generation. With inventive design approaches, longitudinally-pumped oscillators may be able to produce ≥1 W of laser output at the second harmonic wavelength using existing diode lasers. An additional goal of the Phase I effort will be to develop a design for such a device.

Potential Commercial Applications: The resulting devices could serve either as a 1-micron source or as a pump for a commercial Ti:Al_2O_3 laser that could be used in spectroscopy, terrestrial remote sensing, and medical research.

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*** 135** LaRC
89-1-08.07-6000A NAS1-19035
Development of 780- and 792-Nanometer Diode-Laser Pumps for Solid-State Lasers
Spire Corporation
Patriots Park
Bedford, MA 01730
Kurt J. Linden (617-275-6000)

For use in optically pumping the recently available Tm-activated Ho:YAG and Nd:YLF solid-state lasers,

780-nanometer and 792-nanometer, quantum-well, diode-laser arrays will be developed. The diode-laser array is an effective, optical-pumping method because of its high efficiency, high reliability, and small volume and weight. To make this diode-laser pumping scheme a commercial reality, a reproducible and inexpensive process is required. The main contributing factor to the high cost of diode-laser pump arrays has been the low yield of epitaxial material emitting at the proper wavelength. The company has demonstrated the ability to make quantum-well structures of high uniformity over two-inch wafers in a production MOCVD reactor. Building on present 808-nanometer, diode-laser array activities, operational laser arrays will be fabricated and delivered under this project.

Potential Commercial Applications: Applications would occur in pumping several different lasers used for detection of wind shear and atmospheric microbursts, for atmospheric aerosol sampling, and for soliton generation and femtosecond research.

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136 MSFC
89-1-08.08-1122A NAS8-38462
Compact, Lightweight, Expanding-Beam CO_2 Laser Amplifiers for Spaceborne Applications
Science Research Laboratory, Inc.
15 Ward Street
Somerville, MA 02143
Jonah Jacob (617-547-1122)

The expanding beam laser (EBL) is a revolutionary concept for efficient, lightweight, compact CO_2 lasers for space-based laser radar applications. Its main advantage is that it enables the construction of laser power amplifiers having stage gains that are factors of 10-to-30 times greater than with conventional approaches. In the case of the CO_2 laser, efficient power amplifiers with gains of 1000 can be built with no isolation and with negligible losses from amplified spontaneous emission. As a result, the oscillator that provides the injected signal for a master-oscillator power-amplifier (MOPA) can be reduced in energy by 10 to 30 times, thereby cutting the overall laser weight and volume in half. The objectives for Phase I are the detailed engineering design of a CO_2 laser MOPA using the EBL architecture and verification that the EBL amplifier results in the lightest, most-compact, laser-radar system. Using these conceptual designs, a proof-of-principle experiment will also be designed in Phase I.

Potential Commercial Applications: Compact, lightweight CO_2 lasers could be used in laser welding, heat treating, scribing, cutting and drilling, wind sounding, and remote detection of windshear.

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*** 137** MSFC
89-1-08.08-4022 NAS8-38441
Multiple-Diode-Pumped, Ho:Tm:YAG, Planar Ring Laser
Electro-Optics Technology, Inc.
4057 Clipper Court
Fremont, CA 94538
David G. Scerbak (415-651-4022)

Multiple-diode pumping of a planar, monolithic Ho:Tm:YAG, ring laser will be applied to realize a practical, high-power, single-frequency, room-temperature laser at 2.1 microns. Multiple-diode pumping ensures high gain in all regions of the lasing path. This distributed high gain eliminates reabsorption losses in the Ho:Tm:YAG, three-level laser. Diode-pumped ring lasers offer advantages over CO_2 lasers. Ho:TM:YAG ring lasers, by virtue of their monolithic structure, are inherently compact, reliable and lightweight. Lifetimes approaching 20,000 hours, efficiencies greater than 10 percent, and frequency stabilities better than 10 kHz are all possible with diode pumping. Redundancy of critical diode pumps precludes "hard failures". Ho:Tm:YAG lasers at 2.1 microns are eye-safe and should find application as transmitters in NASA's cw and pulsed, coherent, laser radar systems.

Potential Commercial Applications: These devices may have applications in coherent communications with infrared fibers, in windshear detection, and microsurgery and tissue welding.

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138 MSFC
89-1-08.09-8211A NAS8-38451
Space-Sensor, Common-Module Electronics
Irvine Sensors Corporation
3001 Redhill Avenue, Bldg 3 #208
Costa Mesa, CA 92626
David E. Ludwig (714-549-8211)

Electro-optical focal plane arrays (FPA) and their associated read-out electronics are usually unique to the type of instrument in which they reside. The choice of wavelength, detector material, spatial and temporal sample rates, and scene characteristics significantly influence read-out electronics design. Each new application requires a new FPA development. With the advent of Z-plane FPA architectures, the electronics circuitry can now provide programmable analog and digital signal processing channels for each element of a two-dimensional detector array. Thus, it appears possible to develop an innovative, generic circuit concept that will apply to sensors as diverse as high-resolution, visible and infrared imagers, spectrometers, and lightning mappers. The circuit will provide on-board calibration, data compression, image-motion compensation, and background suppression while maintaining low noise, high dynamic range, and low power dissipation. A conceptual design and performance evaluation will be performed during Phase I that would lead to the design, fabrication, and test of a Z-plane-compatible, integrated circuit during Phase II.

Potential Commercial Applications: Spectral imaging for Earth observations, robotics, manufacturing process

monitoring, and analytical instrumentation are possible applications.

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* 139 MSFC
89-1-08.09-8551 NAS8-38467
A Broadband, Multichannel, Precipitation Sensor
Millitech Corporation
P.O. Box 109
South Deerfield, MA 01373
Ellen L. Moore (413-665-8551)

A sensor will be designed for satellite observations of precipitation, sea surface, and atmospheric soundings. This sensor will comprise a common aperture antenna and a Gaussian-optics, frequency multiplexer that will be used with low-noise receivers. The user will be able to scan in two orthogonal polarizations over one decade of frequency at both microwave and millimeter wavelengths. The design approach is to mate a compact, broadband, frequency multiplexer with a high resolution antenna. The expected design is one which would be cost efficient by allowing many bands to be observed simultaneously with one instrument.

Potential Commercial Applications: This system would be used for remote sensing of many different Earth resources, for environmental and weather studies, for navigation, military operations, and intelligence gathering.

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* 140 ARC
89-1-08.10-7780 NAS2-13169
Miniature, Biogenic-Element Analyzer
Advanced Research and Applications Corp.
425 Lakeside Drive
Sunnyvale, CA 94086-4701
Russell E. Stachowski (408-733-7780)

This project will establish a new capability in light-element, X-ray fluorescence analysis that supports accurate quantitative measurement of biogenic elements. The basis for this new capability is a class of innovative, X-ray wavelength-dispersive optical components known as layered synthetic microstructures. These components, when combined with existing energy-dispersive detectors, make feasible the construction of miniature biogenic analyzer systems for NASA missions. Phase I will specify the optimum excitation source, dispersion element, and detector components of the system and provide a calculational end-to-end demonstration of its response properties. These data will provide a foundation for Phase II prototype construction and experimental evaluation.

Potential Commercial Applications: The products could have commercial application in the field of analytical electron microscopy, in support of life science, microelectronic, and advanced materials research and development.

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* 141 JPL
89-1-08.11-5435 NAS7-1078
Adaptive, Rapid-Scanning, Imaging Spectro-Polarimeter
AOTF Technology, Inc.
540 Weddell Drive #6
Sunnyvale, CA 94089
Patrick Katzka (408-734-5435)

The objective of this project is to develop an imaging, ground-based, spectro-polarimeter utilizing state-of-the-art acousto-optical tunable filters (AOTFs). The approach is to use a novel, optical-imaging system designed to provide access to the orthogonally polarized, AOTF images and to use the undeviated central beam for guiding or other purposes. Access time will be less than 25 microseconds. The tuning range will cover 0.3 microns to 3 microns, utilizing a minimum of AOTFs to cover this extended range, and having a variable passband, nominally between 10 and 100 Angstroms at 1 microns. Other aspects of the approach are the use of an integral-instrument, image rotator to allow routine, linear polarization measurements using both AOTF-filtered images; the use of automated control with an interface to the data-acquisition computer; and the implementation of innovative transducer and/or AOTF designs to provide flexible choices of passband shape and/or position(s).

Potential Commercial Applications: Remote-sensing for survey of resources and numerous uses of AOTF in medical, biological, geological, oceanographic, and agricultural fields could result from this project.

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142 ARC
89-1-08.12-9450 NAS2-13166
Efficient, Far-Infrared, Inductive Mesh Filters by Photoelectrochemical Etching
EIC Laboratories, Inc.
111 Downey Street
Norwood, MA 02062
Michael M. Carrabba (617-769-9450)

Instrumentation for far-infrared and *sub-millimeter* spectroscopy generally requires beam splitters and bandpass or cutoff filters that, for these wavelengths, typically have a mesh geometry, with the shape and dimensions of the openings determining the optical properties. A new method for fabricating these filters using light-driven etching of semiconductor crystals promises to provide a variety of hole shapes with narrow hole spacings and highly vertical sidewalls; these characteristics cannot be achieved by the present techniques of etching thin metal foils or winding fine metal grids. Phase I will be used to define the conditions for making 1 cm^2 prototype meshes (e.g., 20 x 20 microns squares on 30 microns centers) in 50-100 microns thick GaAs. Phase II would entail determination of optimal semiconductor-substrate materials and photoelectrochemical processing conditions and the fabrication and evaluation of a variety of filter structures and sets with relevance to specific NASA missions.

Potential Commercial Applications: The filters would apply to far-infrared and millimeter wave astronomy, meteorology, surveillance, and far-infrared lasers. New techniques for producing finely etched vertical structures will have commercial significance in electronics, optics, ink jets, micro-sieves etc.

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143 GSFC
89-1-08.13-3100 NAS5-30866
Low-Cost, Imaging Electron-Multiplier Device
Optron Systems, Inc.
3 Preston Court
Bedford, MA 01730
Anthony Nicoli (617-275-3100)

The goal of this project is to build an imaging electron multiplier (IEM) that offers the low-noise gain of photomultiplier tubes and the imaging properties of conventional micro-channel plates (MCPs) but with high output-current densities. This device incorporates an axially aligned stack of discrete, high-resolution, porous dynodes employing a highly conductive, secondary-electron-emitting material. Its modular design permits tailoring of the device for specific applications. For example, designed as a large-area MCP photomultiplier tube, the IEM is expected to offer a significantly improved signal-to-noise ratio over a conventional MCP. When comprised of a large number of dynode stacks (about ten), the IEM will be capable of functioning as a power micro-channel plate.

*Potential Commercial Applications:*Commercial applications are possible in low-noise imaging photon detectors for astronomy, adaptive optics, surveillance, image processing, optical computing, and machine vision.

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* **144** GSFC
89-1-08.13-8961 NAS5-30870
Backside-Illuminated, Large-Format, Charge-Coupled Devices and Mosaics
Photometrics Limited
3440 E. Britannia Drive, #200
Tucson, AZ 85706-5006
Gary R. Sims (602-623-8961)

This project involves constructing large-format, thinned, backside-illuminated charge-coupled devices (CCDs) and CCD mosaics. The problems associated with uniformly thinning large silicon areas, mounting the thinned membrane to a rigid support such that a desired optical figure is obtained, and making reliable electrical contact to the CCD are addressed in the Phase I work. Successful completion of the Phase I and Phase II work will result in the availability of large-format CCDs and CCD mosaics that exhibit high, stable sensitivity at wave-lengths extending from the near-IR through the VUV. Such devices will be valuable for space- and ground-based astronomy where large focal planes and high sensitivity are required.

Potential Commercial Applications: Applications could occur in space- and ground-based astronomy, optical and electron microscopy, low-light-level underwater imaging, analytical spectroscopy, and surveillance.

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* **145** GSFC
89-1-08.13-9546 NAS5-30850
Fiber Arrays for Low-Background Infrared Astronomy
Infrared Fiber Systems, Inc.
2301-A Broadbirch Drive
Silver Spring, MD 20904
Danh Tran (301-622-9546)

Infrared-transmitting, coherent fiber bundles will be developed for use in astronomical and aerospace spectroscopic systems. These systems could be telescope-coupled for in-flight or ground-based use. Applications include re-mapping pixels to match the detector elements of an infrared, focal-plane-array detector; curved-field correction; multi-object spectroscopy or spectroscopic mapping; image magnification; and remote replacement of the detector. During Phase I, a 25-fiber image-slicer will be constructed for immediate testing at Kitt Peak National Observatory. The fibers will be made from zirconium-fluoride-based glass. Experiments will be conducted on the re-draw technique for producing high-resolution imaging bundles. During Phase II, a massively parallel bundle would be constructed to map the spectral elements from a spectrometer-slit image onto the elements of a one-to-five micron, InSb-array detector. Other infrared imaging bundles using both constant diameter and tapered fibers would also be fabricated.

Potential Commercial Applications: Remote observation of infrared images would be useful for medical and industrial diagnosis, for example, thermal monitoring of electronic systems and thermography inside a living body or a nuclear reactor. Other applications include spectroscopic instrumentation for chemical analysis.

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146 JPL
89-1-08.14-0800 NAS7-1084
Improved Antenna for Synthetic-Aperture Radar Calibrator
Center for Remote Sensing
P.O. Box 9244
McLean, VA 22102
Suman Ganguly (703-848-0800)

The goal for this project is an improved antenna for a synthetic-aperture radar (SAR) calibrator. The improvements sought are low cross-polarization, low side-lobe, low cost and weight, and improved stability. Numerical modeling will be applied to evaluate the performance of several antenna configurations under realistic environments to deter-mine the optimal antenna configuration. A prototype will be constructed, and its performance will be mea-sured in a laboratory.

Potential Commercial Applications: Improved antennas will lower the cost and improve the performance of SAR transponders.

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*** 147** JPL
89-1-08.15-5262 NAS7-1106
Multichannel Occultation Photometer
Sets Technology, Inc.
300 Kahelu Avenue
Mililani, HI 96789
Jonathan Gradie (808-625-5262)

This project responds to the need for an infrared photometer that is capable of acquiring, with near simultaneity, data in at least two selectable passbands (1.0-to-5.2 microns and 8-to-13 microns). The photometer must have high sensitivity, operate with a duty cycle of about 100 percent on-source during chopping, and sample data continuously for one hour at 100 Hz. This project will develop a compact instrument that can operate two state-of-the-art infrared detectors (InSb and Si:As) simultaneously in the same cryogenic dewar. The Phase I objective is to develop detailed conceptual and engineering designs of a prototype instrument and construct a working laboratory-bench model. Experience gained in the laboratory model would be applied directly to development of the prototype instrument during Phase II.

Potential Commercial Applications: This project could lead to applications in ground- and spacecraft-based astrophysical and planetary science; remote sensing applications for geological mapping and forestry; and monitoring manufacturing and industrial processes with emitted radiation signatures.

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148 JPL
89-1-08.15-5262B NAS7-1088
Atmospheric Opacity Monitor
Sets Technology, Inc.
300 Kahelu Avenue
Mililani, HI 96789
Jonathan Gradie (808-625-5262)

This project addresses the development of a low-mass (less than 500 grams), low-power (less than 5 watts) atmosphere opacity monitor for use on spacecraft operating on the surface of Mars and on unmanned or remote, terrestrial atmospheric monitors. The objective of Phase I is to develop detailed conceptual and engineering designs of two potential prototype instrument concepts: all-sky imaging using a low-mass, lens system CCD-array detector to study hourly variant phenomena and a horizon-to-zenith swath system to study daily phenomena at many wavelengths. Both of these systems require innovations in low-mass imaging and electronic systems. The results of Phase I would be applied to development of a prototype instrument under Phase II.

Potential Commercial Applications: This device could be applied to emission monitoring of smokestacks and other industrial processes where opacity measurements are required to meet industrial standards.

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149 JPL
89-1-08.16-0827 NAS7-1082
Wideband, Acousto-Optic, Spectra Analyzer
Aurora Associates
3350 Scott Blvd., Bldg 33
Santa Clara, CA 90504
I. C. Chang (415-967-0827)

The goal of this project is development of a wide band, acousto-optic spectra analyzer (AOSA) for application in IR spectrometers for space astronomy. Its inherent wide bandwidth and parallel signal-processing characteristics make it well suited to this application. The performance goals for development of the AOSA include a 2 GHz bandwidth and a 1 MHz resolution. In Phase I, the theoretical study of feasibility of the AOSA based on two approaches: Bragg-cell efficiency enhancement and the concept of channelized instantaneous frequency measurement.

Potential Commercial Applications: The applications would be in the areas of optical signal processing and computing. Successful development of the small, wide-band processor could lead to compact, special-purpose computers for exploration seismology.

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*** 150** JPL
89-1-08.17-8500 NAS7-1097
Dual K- and C-Band Transponder for Satellite Altimetric Calibration
Interferometrics, Inc.
8150 Leesburg Pike, Suite 1400
Vienna, VA 22182
David B. Shaffer (703-790-8500)

To provide the capability to establish and maintain sea-surface truth for satellite altimeter validation, a dual-frequency (K-band and C-band) transponder that will simulate the surface reflection of ranging pulses transmitted from the TOPEX/Poseidon spacecraft will be investigated. This transponder must receive and transmit on the same frequencies. It must receive the spacecraft transmissions and determine their characteristics in order to transmit replicas. Detection by matched-filter, surface-acoustic-wave (SAW) correlation will enable the generation of chirp replicas of very high precision. Because the transponder is active, the retransmitted chirps will undergo only R^2 power loss rather than the R^4 loss associated with competing systems. These high-power returns will force TOPEX to track the transponder for calibration and orbit determination. The transponder will use the spacecraft ephemeris and known location of the transponder to improve greatly the speed and accuracy with which it can lock onto the spacecraft transmissions.

Potential Commercial Applications: The new altimetric transponder could be applied in environmental protection by monitoring surface vertical distortions at hazardous waste sites and in water resource management

by monitoring the changes in surface height caused by changes in ground water table levels.

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151 JPL
89-1-08.18-0827 NAS7-1093
Acousto-Optic Tunable Filter
Aurora Associates
3350 Scott Blvd., Bldg 33
Santa Clara, CA 90504
I. C. Chang (415-967-0827)

Improved performance of acousto-optic tunable filters (AOTF), which are promising for space-borne optical sensor and instrument applications, is the goal of this project. The full capability of the AOTF is limited by critical deficiencies of the current technology. The Phase I effort for overcoming these deficiencies includes: the improvement of out-of-band rejection to 30 dB by investigating three novel apodization techniques and the development of new, ultraviolet, AOTF materials that are at least ten times better than crystal quartz.

Potential Commercial Applications: Applications are possible in industrial process control and medical instrumentation: for example, as an in situ, thin-film monitor for dielectric control or a rapid-scan spectrometer for cell-biology studies.

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152 GSFC
89-1-08.18-5130 NAS5-30873
Gas-Jet Deposition of Optical Thin-Films for Extreme Ultra-Violet and Soft X-Ray Applications
Schmitt Technology Associates
25 Science Park
New Haven, CT 06511
Bret L. Halpern (203-786-5130)

A gas-jet deposition (GJD) technique will be tested for depositing silicon-carbide films and gold-silicon multilayer films to make high-reflectance mirrors for the extreme UV and X-ray spectral regions. The objectives are to learn if this method can produce the films at an acceptable rate, over useful areas, and with sufficient reflectance to show promise for mirror applications important to NASA's space astronomy missions. The GJD method exploits supersonic gas jets to deposit thin films of metals, semiconductors, insulators, and organic materials at high rates on low-temperature substrates. The gas-jet sources will be modified to sustain microwave discharges for plasma-assisted deposition or equipped with targets for laser vaporization. During deposition, the films will be annealed by pulsed-laser heating and by bombardment with high fluxes of moderate-energy neutral species. In addition, a new approach to coverage of large areas by the periodic deflection of the gas jets will be tested. The optical properties of the films will be characterized.

Potential Commercial Applications: Application may be found in optical components for X-ray lithography, synchrotron beam lines, and silicon-carbide coatings for electronic, photonic, and wear applications.

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*** 153** JPL
89-1-08.18-7513B NAS7-1095
Ion-Beam Deposition of Large-Area, Low-Scattering Metal Coatings
Barr Associates, Inc.
2 Lyberty Way
Westford, MA 01886
Ghanim Al-Jumaily (508-692-7513)

Metal coatings deposited using conventional evaporation are unstable when exposed to such elements of the environment as moisture, heat, and radiation. State-of-the-art space and astronomical applications, such as white-light, all-reflecting coronographs, require coatings with optimum properties. These applications require large-size, super-smooth, high-reflectance mirrors. Ion-beam-based coating techniques have shown great promise to improve the durability and reduce the optical scatter of thin films. Metal coatings will be deposited using conventional evaporation, ion-assisted deposition, and ion-assisted sputtering. Coatings of silver, aluminum, and gold will be examined. Several diagnostic techniques will be employed to examine effects of deposition conditions on the optical properties, optical scatter, and mechanical properties of metal coatings. Scaling of the coating process to coat large surfaces will be examined.

Potential Commercial Applications: Metal coatings are useful for wide-band, high-reflectance surfaces, band-pass metal-dielectric filters, and telescope mirrors and space-based optical telescopes.

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*** 154** GSFC
89-1-08.18-9450 NAS5-30844
Photoetched Echelle Gratings in Silicon
EIC Laboratories, Inc.
111 Downey Street
Norwood, MA 02062
Michael M. Carrabba (617-769-9450)

Echelle diffraction gratings are critical components for spectral analysis of light from stellar and albedo sources. Photo-electrochemical etching (PEC) is a process for producing diffraction gratings directly into semiconducting materials with a high degree of control of reaction rate, lateral uniformity, and groove angle. Phase I will determine the feasibility of making Echelle diffraction gratings in silicon by the PEC method. Silicon possesses the crystallographic properties that would allow direct PEC fabrication of deep, low-pitch, Echelle gratings. Silicon gratings greater than 7.6 cm x 7.6 cm in size are possible since high-quality and large area ($\geq$22 cm diameter) crystals are available. In Phase I, the effects of photo-etchant composition, exposure times, light intensity, masking procedure, and doping density of the Si will be examined. The goal of the project is the production of practical-size Echelle gratings for evaluation by NASA.

Potential Commercial Applications: The gratings would be useful for free-electron lasers and synchrotron light sources and as masters for gratings used in high-resolution, commercial spectrographs. PEC techniques could be used to fabricate solid-state electronic devices, micro-mechanical structures, and sub-millimeter optical filters.

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155 GSFC
89-1-08.19-5976 NAS5-30841
Broadband Source for a Three-Dimensional Reflectometer
TNA Technologies, Inc.
P.O. Box 3118
Bozeman, MT 59715
John C. Stover (406-586-7684)

The technology to take full-hemisphere, reflective or transmissive scatter measurements with fully automated position and polarization control of the instrument now exists. Adoption of this technology will result in an instrument that is highly compatible in terms of operation and data output with those at other government research laboratories. Two significant innovative design features will extend the current state of the art. First is a new source design that uses the FTIR (Fourier transform infrared) spectrometer. It should result in higher performance instrumentation because of throughput and efficiency advantages. The second innovation is the measurement of the four Stokes parameters. A brute force approach requires broadband waveplates to produce and measure the required polarization components. There are two alternatives; one is easier experimentally, and the other is more suitable to automation than the brute force method.

Potential Commercial Applications: This device could be applied in materials research and process and quality control in steel, aluminum, plating, and paper industries.

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156 GSFC
89-1-08.20-9040 NAS5-30865
Time-of-Flight Mass Spectrometry Instrument for Monitoring Contaminants in Space
Schmidt Instruments, Inc.
2476 Bolsover Suite 234
Houston, TX 77005
Howard K. Schmidt (713-529-9040)

A prototype contamination detection and characterization system will be fabricated based on a combination of time-of-flight mass spectrometry (TOF-MS) and quartz crystal microbalance (QCM) technology. A novel ion-source for sampling both gas phase and sputtered ion-species will be constructed, permitting low-level detection of contaminant molecules both before and after deposition on test surfaces. TOF-MS features simple, rugged construction, with high sensitivity and uniform response as a function of mass. Sticking coefficients, re-emission rates, and chemical identity of significant contaminants can be determined using such instrumentation. The objectives of Phase I are construction of a bread-board version of the QCM/TOF-MS system and assessment of requirements for a self-contained, autonomous contamination sensor.

Potential Commercial Applications: Commercial uses could occur in quality and process control and leak and contamination detection.

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157 JSC
89-1-08.21-8442 NAS9-18304
Highly Transparent, Rugged Sensor for Meteoroids and Space Debris
Applied Research Corporation
8201 Corporate Drive, Suite 920
Landover, MD 20785
Siegfried Auer (301-459-8442)

The main purpose of this project is to develop a simple system to measure the velocity vectors of dust particles, particularly those Earth-orbit and interplanetary dust particles of masses of less than one milligram. The instrument--a simple, rugged design--will be a highly transparent sensor system for accurate velocity vector measurement. A catcher could easily be added for chemical and physical analyses of the particles. The objective of Phase I is to design and construct a simple laboratory model and test it using pellets and a dust accelerator (Moorhead, Minnesota or Max Planck Institute, Heidelberg, Germany). The results will establish such critical design parameters such as rod characteristics, rod spacing, electrical shielding, and signal-to-noise ratio for use in Phase II.

Potential Commercial Applications: Applications would be mainly in the design of space structures.

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158 LeRC
89-1-08.22-2719 NAS3-25814
Cryogenic, Ultrasonic, Mass-Flow Meter and Quality Meter
Panametrics, Inc.
221 Crescent Street
Waltham, MA 02254
Lawrence C. Lynnworth (617-899-2719)

Accurate measurement of gaseous hydrogen flow-rate by ultrasound requires new transducers that overcome hydrogen's low acoustic impedance (Z). New ways of mounting these transducers must be found to avoid acoustic short circuits. Two low-Z transducers will be designed. The first uses slow, leaky flexural waves propagating in a conical radiator. The frequency-distance product controls the phase velocity of the leaky flexural waves and the ultrasonic radiation pattern in the H_2 gas. In the second, the gas is sandwiched between a laser-perforated plate and the solid surface of an ultrasonic piston. When the piston is energized, the compressed gas squirts through the perforations as a velocity-transformed pulse having ultrasonic frequency components corresponding to vortices shed by the holes. Both transducers, if successfully developed, would measure the bi-directional flow of low-Z cryogens with response times ≤ 0.1

seconds. Success, however, requires that small-contact-area mounts, slow-wave structures, or other isolation means be perfected.

Potential Commercial Applications: Applications could be in measurement of mass flow rate and quality of a variety of single and two-phase fluids; as a fast-response, bi-directional flowmeter to measure oscillatory and pulsating flows in engines and pumps; and in biomedical measurements of the breathing dynamics.

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09: Spacecraft Systems and Subsystems

159 LaRC
89-1-09.01-1500 NAS1-19015
Control Structure Interaction: Optimization-Based Design Tools
Integrated Systems, Inc.
2500 Mission College Boulevard
Santa Clara, CA 95054-1215
Robert L. Kosut (408-980-1500)

The performance requirements placed upon large structures used in space missions may be most effectively achieved by integrating structural and control design to accrue significant performance benefits with less costly controller hardware. One approach to this problem involves integrating the structural and control design via an optimization approach. This allows a great deal of flexibility in the tradeoff between such design features as weight and power requirements entirely through cost function selection. In prior efforts to use this approach, it was assumed that both the controller gains and the structural parameters could vary continuously over some specified range. This assumption is unrealistic since it is not feasible from either a cost or a technical standpoint to construct a structure where every member is unique. In this project, the structural members will be limited to some predefined set of available elements selected through a combinatorial optimization approach. This will allow for continuously varying controller parameters and discretely varying structural parameters, while still achieving an optimal design.

Potential Commercial Applications: The expected applications would be in the design of large space structures.

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160 LaRC
89-1-09.02-0126 NAS1-19033
A High-Speed, Fault-Tolerant Microprocessor for Space Applications
Spaceborne, Inc.
742 Foothill Boulevard, Suite 2B
La Canada, CA 91011
Constantin C. Timoc (818-952-0126)

Advanced space systems require significant improvements in the throughput and fault tolerance of their guidance, navigation, and control computers. The main objective of this project is to develop a laboratory prototype of a novel, single-chip, fault-tolerant, radiation-hard CMOS, MIL-STD-1750A microprocessor operating significantly faster than existing microprocessors. Phase I consists of a feasibility study of a novel arithmetic unit of the microprocessor. The method for increasing the speed is an innovative, multi-port, general-purpose register array and two separate adders for the mantissa and the exponent of floating point operations. Fault tolerance of the register array will be achieved by an error detection and correction unit based on a modified Hamming code. The combinational logic of the adders employs "fine-grain" fault tolerance. An innovative, differential CMOS logic circuit is used to perform double-rail logic operations for efficient fault detection. Fault correction is achieved by duplicating the double-rail adders. The expected result is a fault-tolerant chip that is significantly more cost-effective than current approaches. The fault tolerance effectiveness will be measured and demonstrated by fault simulation.

Potential Commercial Applications: There is a real need in the military and commercial markets for a single-chip, high-speed, fault-tolerant, radiation-hard MIL-STD-1750A microprocessor.

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*** 161** LaRC
89-1-09.02-3474 NAS1-19004
A Neural-Net Approach to Space Vehicle Guidance
Charles River Analytics, Inc.
55 Wheeler Street
Cambridge, MA 02138
Alper K. Caglayan (617-491-3474)

The numerical algorithms involved in the solution of optimum trajectory and guidance problems are too complex for on-line application with advanced space vehicles. Hence, the current approach to the development of real-time guidance is to use approximation theory to obtain closed-loop guidance laws. Neural networks offer an alternative to the derivation and implementation of guidance laws. This project will formulate the space vehicle guidance problem using a neural network approach and find the appropriate neural net architecture for modelling optimum guidance trajectories. It will train the developed network with a database of optimum guidance trajectories and demonstrate its performance as an on-line classifier. Such a neural-network-based guidance approach can readily adapt to environmental uncertainties such as those encountered by an AOTV during atmospheric maneuvers.

Potential Commercial Applications: The commercial application would be a front end for neural-network software packages and computers for incorporating a priority-system knowledge base into the selection of processing elements and interconnect structures.

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162 JSC
89-1-09.04-0760 NAS9-18333
Novel Direction-Finding for Robotic Tracking in the Space Station
SCS Telecom, Inc.
107 Haven Avenue
Port Washington, NY 11050
Tuvia Apelewicz (516-883-0760)

Conventional radio systems are proving inadequate to support the full and effective utilization of robotics in a space station environment. The tracking and locating of extra-vehicular robots is complicated by radio transmission multipath and station reflections, by the number of simultaneously transmitting robots, by antenna shielding due to the geometry of robot location, and by resolution requirements exacerbated by limited transmission path dimensions. New signal processing techniques are needed to solve these problems. This project will design a direction-finding system to implement space-station-robotic tracking that overcomes these technical limitations by using a unique chip code for individual robot identification. It uses state-of-the-art FFT hardware chips to implement the cross-comparison and detection procedure and discriminates secondary multipath signals.

Potential Commercial Applications: A direction-finding device that can track and locate robots is required for the robotic maintenance at sophisticated electronic equipment for commercial operations in space.

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*** 163** JSC
89-1-09.04-1416B NAS9-18325
Dynamic, Coherently Coupled, Holographic Optical Elements Using Liquid Crystals
Physical Optics Corporation
20600 Grammercy Place, Suite 103
Torrance, CA 90501
Behzad Moslehi (213-530-1416)

A new approach to dynamic optical switching is based on nonlinear liquid-crystal materials and holographic techniques. The firm's holo-crystal switch (HCS) offers high promise of being the precursor to the next generation of dynamic holographic optical elements. Its primary innovation is dynamically variable reflection or transmission. As a holographically fabricated element, the device is flexible with respect to its diffractive properties. The HCS is the first-of-its-kind to employ advanced, nonlinear liquid-crystal materials to modulate the phase relationship between spatially coupled sub-holograms, leading to significant variations of the effective reflectivity. The HCS will benefit future NASA missions by replacing conventional microwave systems in space tracking and imaging applications. It will apply as well to fiber-optic and free-space communication, optical computing, remote sensing, and altimetry.

Potential Commercial Applications: This novel holo-crystal switch would find applications in diverse areas such as imaging systems, robotics, fiber-optic and free space communications, optical computing, remote sensing, and altimetry.

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*** 164** MSFC
89-1-09.05-3200 NAS8-38440
Novel Composites for Protection Against Orbital Debris
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02154-1196
J. J. Gassner (617-890-3200)

This project investigates a unique combination of materials for space bumpers to counter the threat posed to pressurized vehicles by micro-meteoroids and man-made orbital debris in space. The material combinations to be examined include planar composites possessing rod-like reinforcement in the thickness (Z) direction as well as thin sandwiches of these materials in which Z-reinforced sections are separated by a layer of low-density foam. A key aspect of this concept is the Z-direction reinforcement, a dense, low-shock-compressibility metal to assist in fragmenting a projectile and dispersing the fragments over a wide area. This concept is the small-scale analog to the use of long-rod penetrators to defeat ground vehicle armor. In this case, the penetrator rods are stationary with respect to the vehicle and are contained within an organic matrix composite material, while the material to be defeated is moving.

Potential Commercial Applications: No commercial applications currently exist for improved space bumpers per se. However, there may be technology transfer to other areas where protection at high velocities is sought, including products for law enforcement agencies and the military.

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*** 165** GSFC
89-1-09.06-7062 NAS5-30856
Automated Seal-Flaw Detection
Winzen International, Inc.
12001 Network Blvd Suite 200
San Antonio, TX 78249
Thomas M. Lew (512-692-7062)

This project addresses the development of an automated, real-time flaw detection system for evaluating heat seals of scientific balloons. Several measurement devices will be tested for their ability to distinguish a flawed seal sample from a good seal. Measurement devices under consideration are passive thermal-wave detection, thermal-wave through-transmission, and optical through-transmission. Based on the test results, the best method for the application will be determined, the feasibility of further development of the concept will be assessed, and components for a prototype system will be specified.

Potential Commercial Applications: The concept is potentially of great interest to packaging and food

industries where efficient and reliable heat sealing of thin films is important.

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* **166** GSFC
89-1-09.07-6410 NAS5-30862
A Low-Thermal-Conductivity Connector
Tracer Technologies, Inc.
20 Assembly Square Drive
Somerville, MA 02145
Fraser Walsh (617-776-6410)

The objective of the project is to develop a low-thermal-conductivity connector using a laser-based process. The connector will consist of a graphite core, a metal interphase layer, and a high-T_c superconducting ceramic surface layer. Lengths of the fiber wire will be formed and tested for electrical properties; surface morphology and chemistry will be characterized using SEM and Auger profile analysis.

Potential Commercial Applications: The material prepared will have commercial application as a low-thermal-conductivity connector for low temperature sensors in infrared sensing devices, magnetometers, and SQUIDS.

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167 GSFC
89-1-09.07-9722 NAS5-30852
High-Temperature Superconductor for Passive Magnetic Bearings
HITC Superconco, Inc.
140 Tullytown Road
Bordentown, PA 19007-6302
Robert D. DeLuca (215-943-9023)

This project defines a demonstration on the advantages of high-T_c superconducting ceramics (HTSC) in applications currently requiring the use of expensive and complex magnetic bearings. Because of their ability simultaneously to expel and trap or pin magnetic flux, HTSCs provide the potential for passive magnetic bearings that are self-stabilizing. The advantages of passive magnetic bearings are reduced stored power or power generation requirements and reduced weight and volume for rotational equipment on a spacecraft. The objective of this work is a prototype magnetic bearing capable of operating at or below liquid nitrogen temperature. It will incorporate bulk HTSC components with flux expulsion and flux pinning properties optimized for a passive bearing; an insulation and refrigeration system to demonstrate operating characteristics and bearing stability over extended periods of time; and design parameters for a Phase II HTSC magnetic bearings.

Potential Commercial Applications: This project will set the foundation for frictionless, noiseless, vibration-free, and non-power consuming bearings for a host of rotating system applications with high and variable loadings.

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168 GSFC
89-1-09.08-9444 NAS5-30874
Spacecraft Attitude Determination Using AI and Attitude Measurement Information Theory
Microcosm, Inc.
2601 Airport Drive, Suite 230
Torrance, CA 90505
James R. Wertz (213-539-9444)

Artificial intelligence techniques will be applied in conjunction with attitude measurement information theory pioneered by the principal investigator to develop a system capable of data rejection, ambiguity resolution, attitude determination, and bias calibration. This technique maximizes the information derived from a given measurement set including identification of bad data; identification of alternative data solutions (corresponding, for example, to the discreet solutions available from the intersection of two cones); and the identification of the presence of biases in the solution set. Phase I will establish feasibility and efficiency by developing a rule-based system which can be easily applied. These rules will be implemented in software in Phase II. Because the results of the project can be clearly viewed and judged by an observer, it will be possible to identify efficiently any algorithmic errors and to develop a high degree of confidence in the robustness of the final solution.

Potential Commercial Applications: Non-space applications include remote sensing, terrestrial navigation, and photo interpretation.

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169 JSC
89-1-09.09-3100 NAS9-18323
Low-Voltage, Thin-Film Electroluminescent Phosphor
Optron Systems, Inc.
3 Preston Court
Bedford, MA 01730
Camille F. Fuleihan (617-275-3100)

High-resolution, full-color, thin-film electroluminescent, flat-panel displays for critical spacecraft applications will require higher pixel densities than can be supported by conventional thin-film electroluminescent (TFEL) phosphor technology. This is due to the high operating voltages required by these devices and the likelihood of arcing at small pixel spacings. However, it may be possible to reduce the required operating voltages by utilizing such recently developed deposition-enhancement techniques as ion-beam-assisted deposition in conjunction with new, dielectric films based on diamond-like hydrogenated amorphous carbon to reduce the thickness of the phosphor layers. Reduced voltage requirements would also allow development of more compact and lightweight monolithic displays with higher brightness, longer lifetimes, and higher resolution than are achievable with conventional TFELs.

Potential Commercial Applications: The low-voltage thin-film electroluminescent phosphor would have commercial applications in high-performance flat-panel

display systems. In addition, the device may prove useful for large-area light panels.

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170 JSC
89-1-09.09-4995 NAS9-18303
Flat-Panel, Multicolor Display Based on Integrated Optic Scanner
APA Optics, Inc.
2950 N.E. 84th Lane
Blaine, MN 55434
William Phillips (612-784-4995)

The overall objective of this project is to develop a low-power, compact, multicolor, flat-panel display. The approach is based on illuminating a three-color phosphor screen with an infrared semiconductor laser diode and scanning it with an integrated-optics-based, low-power laser scanner. The firm is developing a laser scanner which has no moving parts, is very compact, and has the potential to provide very high spatial resolution over a large deflection angle. A 1.06-micron diode-pumped laser, when used in conjunction with "unconversion" phosphors, emits light in the visible spectrum. Successful development of the concept will result in a display with the desired small-volume, low-power features for space workstation applications. In Phase I, the interaction of the laser scanner with the three-color phosphor screen will be evaluated. The requirements and configurations for all the components of the display will be specified and the laser-phosphor interactions will be characterized. In Phase II, a feasibility demonstration unit would be built.

Potential Commercial Applications: Color displays are widely sought for both commercial and military applications.

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171 JSC
89-1-09.09-9511 NAS9-18327
Universal, Bilateral, Robotic Controller
Quanta, Inc.
2778 Hargrove Road, Suite 345
Smyrna, GA 30080
Gary V. McMurray (404-955-5811)

Teleoperator systems are distinguished from other types of robotic systems by the active participation of a human operator. In cases where artificial intelligence can allow partial removal of the person from the loop, it is still desirable to have a fully functional human teleoperator back-up system. This project will develop a universal bilateral robotic controller for the teleoperation of robotic manipulators composed of a bilateral manual controller (joystick), communications hardware, and mapping software. The Phase I objective is to design a counterbalanced, lightweight, compact joystick that provides force feedback to the operator. New mapping techniques will be investigated to provide the operator with a transparent interface. Phase II activities would include the fabrication of the universal, bilateral, robotic controller system and testing with several commercially available manipulators.

Potential Commercial Applications: Applications of the controller are many: space systems, underwater exploration, radioactive material handling, manufacturing.

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*** 172** JSC
89-1-09.11-0851A NAS9-18329
High-Density, Chemical-Thermal Storage System for Low-Gravity Environments
Rocky Research
P.O. Box 1086
Boulder City, NV 89005
Uwe Rockenfeller (702-293-0851)

Thermal storage for manned spacecraft and planetary bases has the potential to reduce the overall system mass through load leveling. Today's thermal storage concepts, however, are inadequate for space application because the energy densities are low (333 kJ/kg for ice used in cool-storage) and none of the environmentally safe systems can provide dual-temperature (hot and cool) storage. Therefore, a water-based chemical absorption process will be developed to provide cool and hot storage at energy densities three times higher than obtainable with ice, eutectic salts, clathrates, or sensible thermal storage systems. This system is based on the absorption of water vapor into selected aqueous solutions It is environmentally safe and benefits from low-gravity environments. The Phase I objectives are to identify suitable sorption systems, measure the key properties, design the principal hardware configuration, and provide experimental proof-of-principle. Phase II would then focus on the determination of heat and mass transfer additives and the construction and test of a prototype thermal storage system.

Potential Commercial Applications: The results of this project would be directly applicable for commercial HVAC, refrigeration, and industrial waste heat recovery and reuse.

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173 GSFC
89-1-09.12-3200 NAS5-30867
Heat Pump for Space Thermal Bus
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02154-1196
Andrew C. Harvey (617-890-3200)

Various space systems will require heat pumps to lift heat to a common thermal bus and radiator system, e.g., a moon station with a relatively high radiator temperature. A small, high-pressure compressor that avoids the problem of lubricant in the working fluid loop is needed. Phase I will demonstrate a prototype of a compact, high-efficiency, long-life, dry ammonia compressor at high head-pressure. In addition, system trade-offs will be reviewed for probable applications and design refinement for zero-G demonstration.

Potential Commercial Applications: A high-pressure, dry-head compressor will permit commercial refriger-

ation with benign-to-ozone refrigerants for which compatible oils do not yet exist.

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*** 174** GSFC
89-1-09.12-3800A NAS5-30854
Magnetic Bearings for Miniature, High-Speed Turbomachines
Creare, Inc.
P.O. Box 71
Hanover, NH 03755
Herbert Sixsmith (603-643-3800)

This project is aimed at the development of a novel electromagnetic (E-M) bearing system specifically for miniature, high-speed turbomachines used in spaceborne turbo-Brayton cryocoolers. Compared with gas bearings currently in use, E-M bearings provide greater ruggedness and will allow for operation at lower temperatures and in vacuum environments. These attributes offer potential improvements in cryocooler efficiency and reliability, particularly at the temperatures and refrigeration capacities associated with surveillance sensors. In this project, the technology of active E-M bearings developed for large shaft sizes will be extended to miniature turbomachines. The key challenge is the development of miniature shaft position sensors that are needed to control the bearing force. In Phase I, an E-M bearing using a novel capacitive sensor will be demonstrated. The detailed design, development, and demonstration of a complete miniature E-M bearing system in a prototype turbomachine is planned for Phase II.

Potential Commercial Applications: Proven E-M bearing technology for miniature, high-speed machines will have immediate benefits in advancing the efficiency and reliability of low-power cryocoolers that are needed for spaceborne surveillance sensors.

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175 GSFC
89-1-09.12-4000 NAS5-30860
A High-Efficiency, Low-Vibration, Long-Life, Stirling Cryogenic Pre-Cooler
Stirling Technology Company
2952 George Washington Way
Richland, WA 99352
Peter Riggle (509-375-4000)

A technology demonstration model (TDM) model of a high-efficiency, long-life, low-vibration Cryoflex™ double-expansion cryogenic pre-cooler will be developed. This device would be used as a standard flight pre-cooler for heat removal from lower-temperature cryocooler stages. The key objectives for the pre-cooler are high efficiency, low vibration, and a life of 10 to 15 years. The pre-cooler will remove heat from sources in the 20 K temperature range. High efficiency will be achieved through the minimization of dead volume in a double-expansion Stirling device, careful selection of advanced regenerator technology, optimized electric motor design, and flexural bearings for high mechanical efficiency. Co-linearity of oscillating masses coupled with either dual opposed pistons or an active balancer with adaptive control will result in trace levels of vibration. Flexural bearings and gas clearance seals will provide 10 to 15 year life. The Phase I objective is completion of the TDM conceptual design. Phase II objectives include design, fabrication, assembly, testing and evaluation of the TDM.

Potential Commercial Applications: Applications include cooling of medical sensors, emerging superconductivity applications, and gas liquefaction for laboratory applications.

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*** 176** GSFC
89-1-09.12-6551 NAS5-30861
Sintered-Powder, Artery-Free Wicks for Low-Temperature Heat Pipes
Thermacore, Inc.
780 Eden Road
Lancaster, PA 17601
John H. Rosenfeld (717-569-6551)

Current NASA requirements include the need for one-meter-long, low-temperature heat pipes capable of carrying 5 to 50 W of power with evaporator heat fluxes as high as 1 W/in^2. Recent advances have resulted in sintered wicks capable of meeting the above transport requirements with five to fifteen times the lift capability and ten to one-hundred times the evaporative heat transfer coefficient of grooved wicks. All of this can be achieved without the need for arteries. The objective of this project is to demonstrate the capabilities of sintered-powder-metal heat pipes to meet short-term NASA requirements while demonstrating order-of-magnitude improvements in evaporative heat transfer coefficient and lift capability. The Phase I effort will update the design requirements; develop high-permeability sintered wicks; design a full-scale heat-transport system; and demonstrate a meter-long, proof-of-concept heat pipe for operation at 100 K.

Potential Commercial Applications: Applications include cryogenic and low-temperature heat pipes capable of operation in vibrating environments and against substantially increased G-loads compared to currently available products.

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177 MSFC
89-1-09.13-0851A NAS8-38469
High-Lift, Heat-Actuated, Solid-Vapor Heat Pump for Simultaneous Refrigeration and Water Heating
Rocky Research
P.O. Box 1086
Boulder City, NV 89005
Uwe Rockenfeller (702-293-0851)

Refrigeration as well as hot water heating is needed on manned spacecraft. To obtain low-mass and energy-efficient equipment, coordinative complex compounds--a special class of non-toxic, solid-vapor media--will be applied for a dual-duty thermodynamic cycle that provides refrigeration and hot water heating simultaneously. Such cycles can be driven with rela-

tively low-temperature waste heat (400 K to 500 K) or with electric power. Current cycles and media do not allow for dual-duty cycles without significant penalties in performance and reliability. It is, therefore, necessary to develop unique coordinative compounds, the chemical and physical properties of which allow for high-efficiency, low-weight, dual-duty heat pump operation. In Phase I, proof-of-principle hardware will be designed, built and operated under actual heat pump conditions. The hardware will not require any moving parts and will operate under zero gravity without phase separation.

Potential Commercial Applications: Commercial applications of heat pump cycles are primarily in the HVAC, refrigeration, and thermal storage sector.

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178 MSFC
89-1-09.13-3800 NAS8-38436
Condenser Design for Alkali-Metal Thermoelectric Conversion Systems
Creare, Inc.
P.O. Box 71
Hanover, NH 03755
Christopher J. Crowley (603-643-3800)

This project relates to energy conversion systems that utilize a liquid-vapor phase change with liquid metals, in particular, alkali-metal, thermoelectric conversion (AMTEC) systems. These thermally regenerative, electrochemical devices for the direct conversion of heat to electrical energy are being considered for use in space nuclear and solar power generation. AMTEC systems are good candidates for space power applications because they have high efficiency, long life expectancy, redundancy, and no moving parts. The objective of this project is to assess the performance of a novel condenser design for liquid metals, with specific application to AMTEC devices that are of immediate interest. This design for a thin-film condenser is based upon capillary principles, which take advantage of the high surface tension of liquid metals.

Potential Commercial Applications: AMTEC technology could be applied to solar power conversion systems for Earth-based power systems.

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* **179** MSFC
89-1-09.13-6551 NAS8-38437
Composite Material Heat Pipes
Thermacore, Inc.
780 Eden Road
Lancaster, PA 17601
Nelson J. Gernert (717-569-6551)

This project will demonstrate the feasibility of using carbon-composite materials, recognized for their significant strength-to-weight ratio and stiffness, in the construction of ambient-temperature heat pipes. It will link a lightweight composite material with a high-performance, aluminum powder-metal-wick structure to yield a heat pipe with an outstanding power-to-mass ratio. Higher heat transport and lower mass will benefit future thermal control systems on NASA, military, and commercial spacecraft as well as for use on future lunar and planetary bases. Technical feasibility will be demonstrated through the design, fabrication, and test of a proof-of-principle composite heat pipe.

Potential Commercial Applications: Applications are primarily for thermal control systems in spacecraft.

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* **180** MSFC
89-1-09.13-8122 NAS8-38453
Finite-Element, and Adaptive-Grid Thermal Analyzer with Enhanced Graphics Capability
Huntsville Sciences Corporation
3315 Bob Wallace Avenue, Suite 107
Huntsville, AL 35805
James V. McAnally (205-536-8122)

A new thermal analysis code will be developed employing methods that are currently being used successfully in computational fluid dynamics. The finite-element thermal analyzer will solve heat conduction equations for non-homogeneous and anisotropic materials and will determine the transient and steady-state thermal characteristics for structures of arbitrary shape and material composition. From user input describing the structure being modeled, the code will generate the geometry and element mesh for the thermal computational domain. Modern graphics software, installed on an engineering workstation along with the new code, will permit checking of the input geometry prior to the thermal conduction run. Environment data will be input automatically, and the results will be automatically down-loaded to stress analysis codes. The procedure will be a fully interactive, user-friendly operation.

Potential Commercial Applications: Applications would include the design of aircraft, HVAC systems for large buildings, and power plants. Uses could occur in the study of atmospheric phenomena such as thunderstorms, tornados, and thermal inversions.

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181 MSFC
89-1-09.14-8561 NAS8-38457
Integrated, CAD, Venting Analysis Package
Remtech, Inc.
3304 Westmill Drive
Huntsville, AL 35805
G. Hamilton Woods (205-536-8581)

A standardized computer code will be developed to analyze the venting of components for which pressure transients exist, ranging from pressurized to free-molecular vacuum conditions. This code will not require that a user be a specialist in venting methodologies and will use conventional CAD techniques in its execution. A standardized code is needed to assure adequate attention is given to the venting requirements of space hardware for safe deployment. Development of a standardized venting analysis package will require the integration of a venting code for continuum flow, another for rarefied flow, a CAD package to provide a

user interface, and a data base of flow characteristics for complex vent structures. This code will provide a tool for pre-flight certification of all flight hardware and for the design of space-based experiments and manufacturing processes.

Potential Commercial Applications: The code will be applicable to the design of hardware for manufacturing in space (crystal growth and pharmaceuticals). Ground-based applications include vacuum deposition research and development, crystal growth studies, and pharmaceutical production research.

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10: Space Power

*** 182** MSFC
89-1-10.01-0540 NAS8-38461
Integrated Power and Attitude-Control System for the Space Station
Satcon Technology Corporation
12 Emily Street
Cambridge, MA 02139-4507
Richard L. Hockney (617-661-8942)

Integrated power- and attitude-control systems (IPACS), which store energy in the momentum wheels used also for spacecraft attitude control, were shown in studies conducted a decade ago to have advantages over other contemporary energy-storage and attitude-control systems. Recent technology advances in composite rotors, magnetic bearings, and power-control electronics trigger new optimism regarding the feasibility and merits of IPACS. The focus of this project is to define an advanced IPACS and to evaluate its merits for the NASA Space Station and other applications. A design concept will be developed to establish the system feasibility and performance capability. A system-level trade study, including life-cycle costing, will be performed to define the merits of the system relative to two other candidate systems. Prototype hardware demonstrating key technical issues would be developed and tested as a Phase II effort.

Potential Commercial Applications: Applications are expected mainly for space systems.

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*** 183** LeRC
89-1-10.01-3203 NAS3-25825
Flexible, Lightweight, Amorphous-Silicon Solar Cells Tuned for AMO Spectrum
Iowa Thin Film Technologies, Inc.
Suite 607, ISIS - ISU Research Park
Ames, IA 50010
Frank Jeffrey (515-294-7732)

A new type of amorphous-silicon solar cell will be fabricated and monolithically interconnected on polyimide film using continuous roll-to-roll processes developed specifically for polyimide. This technology, tailored for space use, will provide a great improvement over current technologies in both power-to-mass ratio and cost. The device structure consists of an amorphous-silicon p-i-n diode deposited on 2 mil metalized polyimide. A transparent conductor is deposited on top of the diode structure, giving a total device thickness of less than 1 micron. In Phase I, several innovations that ensure device stability and improve device efficiency in the space environment will be studied. These involve modifying the top layer to improve blue and near UV responses, establishing deposition procedures for fabricating tandem-junction devices of layers of amorphous-silicon and insulators with different bandgap levels, and developing a lower bandgap SiGe bottom layer in the tandem cell.

Potential Commercial Applications: Applications would occur mainly for space missions in high Earth orbit and on lunar and Mars surfaces.

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*** 184** LeRC
89-1-10.01-4310 NAS3-25875
New Thermionic Converter for Out-of-Core Space Power System
Advanced Energy Technology, Inc.
16966 Cloudcroft Drive
Poway, CA 92064
Gary O. Fitzpatrick (619-455-4310)

This project concentrates on the application of an out-of-core NETCON (new thermionic converter) to a space nuclear-power system. The emitters are typically 0.5 cm in dimension. The emitter and collector are separated by less than 0.5 mils (~12 microns), with operation in the quasi-vacuum (unignited) mode. The inter-electrode gap is set by the thermal expansion of a ceramic pedestal supporting the emitter. Heat transport to the emitter is by radiation. A good lead efficiency, typically 10 percent or more, is achievable at a relatively low emitter temperature of 1300 K and a collector temperature 850 K. This contrasts with an emitter temperature of 1700 K or more for the normal, ignited-mode converter. Systems analysis and a proof-of-principle NETCON cell will be constructed and tested for reliability in Phase I. Phase II will begin the product development of an out-of-core NETCON for application with a nuclear reactor.

Potential Commercial Applications: Low work function collectors (~1 eV) will result in high thermionic converter efficiency at low collector temperature for solar and other terrestrial power systems.

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*** 185** LeRC
89-1-10.01-4688 NAS3-25888
Composite Regenerator for Stirling Engine
Energy Science Laboratories, Inc.
P.O. Box 85608
San Diego, CA 92168
Timothy R. Knowles (619-455-4688)

This project will investigate the use of carbon-carbon and carbon-ceramic thermal composite materials in regenerators for Stirling engines. The goal is to obtain high-thermal-performance regenerator structures

having a low flow-impedance, small dead volume, and dimensional stability over a wide temperature range. Enhancement of gas-side heat transfer with coated graphite fibers crossing the gas-flow channel will also be considered. The scope of work includes design and fabrication of regenerator components using graphite fibers with carbon- and ceramic-matrix materials. Thermal and mechanical testing will establish the effectiveness of heat transfer in these materials and their mechanical stability under the dynamic, hot-flow conditions of high-power Stirling engines. Thermal test data will be analyzed using composite-material numerical models. Preliminary design of an annular composite regenerator will be developed based on the results obtained in Phase I. A prototype regenerator would be fabricated in Phase II and tested in existing space Stirling engines.

Potential Commercial Applications: These regenerators may improve the efficiency of all types of Stirling engines for use in terrestrial and space power generators and in automobiles.

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186 LeRC
89-1-10.01-7972 NAS3-25885
Constant-Temperature Heat Storage in Metal Hydrides
Hydrogen Consultants, Inc.
12420 North Dumont Way
Littleton, CO 80125
Franklin E. Lynch (303-791-7972)

Thermal storage is a crucial element of solar-dynamic space power systems. Storing heat in solid-liquid phase-change materials is not ideal. These materials are usually highly corrosive salts, and undercooling and heat-transfer temperature differentials cause significant deviations from ideal isothermal conditions. Metal hydrides are equivalent to molten salts in terms of heat storage per unit mass but store more heat per unit volume. In addition, hydrides may enable recovery of stored heat without a reduction in temperature. This effect may be achieved by using pairs of metal hydrides operating in tandem to pump waste heat from the radiator loop to the receiver. A temperature swing in one of the two hydrides overcomes the irreversible energy losses of storing and recovering heat from the other. In effect, this provides isothermal heat storage for maintaining rated output from the power system while the stored heat is recovered. Phase I would compare alternate concepts and prepare for the fabrication of a ground test article in Phase II.

Potential Commercial Applications: Hydride thermal storage could be applied in terrestrial solar electric power and in thermal load-leveling for batch processing at high temperatures in chemical industries.

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187 JPL
89-1-10.02-6901 NAS7-1081
Rechargeable Lithium/Titanium-Disulfide Cells with Long Cycle-Life
Wilson Greatbatch Ltd.
10000 Wehrle Drive
Clarence, NY 14031
Esther S. Takeuchi (716-759-6901)

The objective of this project is the development of an AA lithium/titanium-disulfide rechargeable cell with an energy density above 100 Wh/kg and with a cycle life of 1000 discharge-charge cycles. The project will focus on the design, assembly, and testing of AA cells in practical hardware. Experimental design techniques will be used to investigate modifications of anode, cathode, and electrolyte. Data analysis of the experiment results will determine the variable having the greatest impact on cycle life and any interaction occurring between variables. Phase II efforts would concentrate on the area in greatest need of improvement for a cell with the desired performance specifications.

Potential Commercial Applications: An advanced rechargeable battery could potentially fill any segment of the current $8 billion rechargeable battery market; early uses would most likely be in the specialized cell market.

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188 GSFC
89-1-10.03-7270 NAS5-30843
Nickel-Cadmium Battery Separator Design and Development
Giner, Inc.
14 Spring Street
Waltham, MA 02254-9147
Larry Swette (617-899-7270)

This project addresses the development of a long-term replacement separator for aerospace Ni-Cd cells. The Pellon 2505 nylon separator, which has demonstrated more than five years of low-Earth-orbit (LEO) cycling in Ni-Cd cells, is no longer available. The alternative nylon separator, Pellon 2536, is not a direct replacement in terms of cell performance. A fundamental concern is that the design and fabrication of Ni-Cd cells have been empirically adjusted to accommodate the deficiencies of Pellon 2505; that is, nylon-based separators are chemically unstable in the cell environment and have not been optimized for this application. A replacement separator will be developed with materials that are essentially inert in the cell environment. The physical properties, primarily electrolyte retention and oxygen-transport, will be permanent and optimized for sealed Ni-Cd, LEO-cycling operation.

Potential Commercial Applications: The novel separator could be applied to communication satellites. In addition, a KOH-stable separator may be applicable to other sealed alkaline batteries as an incremental improvement in performance, reliability, and life.

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* **189** LaRC
89-1-10.04-6000 NAS1-19028
Vertical, Multijunction, Photovoltaic Cells with Buried Silicide Interconnections
Spire Corporation
Patriots Park
Bedford, MA 01730
Fereydoon Namavar (617-275-6000)

Vertical, multi-junction cells will be examined for photovoltaic conversion of high-intensity laser radiation at 1.06 microns. The series-connected, multi-junction structure results in the low series resistance required for efficient energy conversion. A small junction-width, furthermore, would make possible efficient collection of long-wavelength light without a long carrier-diffusion length, resulting in good radiation resistance. In order to achieve the small junction-width (10 to 20 microns), ion-implanted silicides will be used for the metal interconnection layers. $CoSi_2$, which has a high conductivity and a small lattice mismatch with silicon, can be formed as a buried layer by ion implantation of cobalt and annealing. High-quality, epitaxial silicon can be grown on the top layer after this process. Thin films produced by this method are generally coherent and uniform, and their interfaces are sharp and free from contamination. In addition, buried silicides act as a getter of their own metal from the bulk silicon, preventing contamination of the solar cell active layer by the implanted metals.

Potential Commercial Applications: The results of this project would apply to space-to-space power transmission.

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* **190** MSFC
89-1-10.06-8911 NAS8-38442
Intelligent Protection System for Space Power Applications
Micon Engineering
One Graham Road
College Station, TX 77845
R. Page Heller (409-690-8911)

The purpose of this project is to develop an intelligent, power-distribution protection system for space power applications. Such a system offers significant advantages over conventional protective devices and would provide high reliability for the power system. An automated protection system would monitor the health of the distribution circuits, clear circuit segments that are not healthy, and reconfigure the system to provide continuity of service to critical loads. The system would take advantage of knowledge-base and learning-system approaches to maximize information about the system at all times. Phase I objectives are to identify and evaluate the functions to be performed by the automated protection system. Various approaches involving fault identification, protection, monitoring, control, and configuration-recovery actions will be investigated for feasibility and effectiveness of application to a space-borne system.

Potential Commercial Applications: Concepts to be developed in this project would be applicable to terrestrial power-protection systems including land-based and ship-borne systems.

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191 JPL
89-1-10.07-9450 NAS7-1092
Robust High-T_c Ribbon for Power Transmission
EIC Laboratories, Inc.
111 Downey Street
Norwood, MA 02062
James D. Klein (617-769-9450)

This project will develop a method for producing flexible, high-T_c, superconducting ribbons for space power transmission applications. It will address mechanical integrity, critical-current density, and scale-up capability essential for the use of ceramic superconductors. Dual, ion-beam deposition techniques will be employed to grow films of $YBa_2Cu_3O_7$ and $Bi_2Sr_2Ca_2Cu_3O_x$ on a textured, metallic-foil substrate. The markedly oriented grain structure provided by epitaxial growth will permit high critical-current densities in the plane of the polycrystalline, superconducting material. Robust mechanical properties will result from the metallic substrate and the inherent flexibility of the thin foil design. Commercial production would utilize multiple-beam, sputter roll coaters to give a wide, continuous sheet of conductor foil that would be slit and wound for each application. Phase I will demonstrate the production of crystallographically oriented, superconducting thin films on metal foil substrate. Process refinement, extension to other superconducting oxides, and scale-up technology would occur in Phase II.

Potential Commercial Applications: A flexible, high-T_c superconductor ribbon having a high critical-current density would have commercial application in magnets, electrical machinery, power transmission, and shielding applications.

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11: Space Propulsion

* **192** LeRC
89-1-11.01-0321A NAS3-25830
Simultaneous Measurement of Temperature, Size, and Velocity of Drops in Sprays
Aerometrics, Inc.
894 Ross Drive, Unit #105
Sunnyvale, CA 94089
William D. Bachalo (408-745-0321)

Theoretical models of spray-combustion processes require experimental validation before they can be used with sufficient confidence for the design of propulsion engines. Data required for validation include--apart from various gas phase flow properties--the size, velocity, and temperature of moving droplets. Currently, the simultaneous measurement of droplet size and velocity is possible with a phased-Doppler-particle-analysis (PDPA). However, no instrument is available for the measurement of droplet temperatures.

This project, therefore, describes the development of an innovative instrument for the non-intrusive and simultaneous measurement of temperature, size, and velocity of individual droplets in reactive spray environments.

Potential Commercial Applications: This instrument could be applied for research in the aerospace, aeronautical, and automotive industry as well as in government laboratories and universities.

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*** 193** LeRC
89-1-11.01-4577 NAS3-25887
A Catalytic, Thermal Management System for Hydrogen-Fueled Injection Vehicles
Accel Catalysis, Inc.
Technology Innovation Center
Iowa City, IA 52242
Katherine B. Gloer (319-335-4457)

A cooling system utilizing the endothermic conversion of para- to ortho-hydrogen has the potential to meet the requirements for thermal management in hydrogen-fueled injection vehicles. This project will determine the feasibility of developing such a cooling system using new, alumina-supported formulations as catalysts for the conversion of para- and ortho-hydrogen. New catalyst materials will be prepared to contain paramagnetic, transition-metal ions dispersed in high-surface-area, porous alumina. They will be prepared using various methods: super-homogeneous co-precipitation, sol-gel formation, support impregnation, and combinations of these. These catalysts will be characterized by determination of metal-ion content, total surface area, pore volume and average diameter, and magnetic susceptibilities. Various activation techniques will be applied to determine their influence on catalytic activities. These will be evaluated by measuring the rate of conversion of ortho- to para-hydrogen upon cooling from ambient temperatures to liquid nitrogen temperature (77 K).

Potential Commercial Applications: A market exists for catalysts used for the conversion of ortho- to para-hydrogen during hydrogen liquefaction.

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*** 194** LeRC
89-1-11.01-4707 NAS3-25837
High-Temperature, Oxidation-Barrier Coatings for Refractory Metals
Electroformed Nickel, Inc.
283 Winfield Circle
Corona, CA 91720
Glenn A. Malone (714-371-4704)

When exposed to high-temperature, oxidizing environments, many refractory metals form volatile oxides and erode at appreciable rates. Several noble metals are refractory in nature but are far less susceptible to oxidation. Such metals can be electro-deposited from aqueous solutions in thin coatings on various substrates to form oxidation barriers. In this project, refractory metal structural devices will be protected in this way to demonstrate that electro-deposition of noble metals can overcome the size, configuration, and cost disadvantages of other fabrication techniques.

Potential Commercial Applications: Noble metal coatings on refractory substrates could be applied to aircraft engine turbine blades, chemical reaction vessels, and liquid metal handling and other corrosive chemical systems.

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*** 195** MSFC
89-1-11.02-0333 NAS8-38438
An Eulerian-Lagrangian Analysis for Liquid Flows with Vapor Bubbles
Scientific Research Associates, Inc.
P.O. Box 1058
Glastonbury, CT 06033
Jayant S. Sabins (203-659-0333)

An analysis for liquid flows containing vapor bubbles--such as those which occur in bearings, seals, and pumps in liquid rocket engines--will be developed. The approach is based on a combined Eulerian-Lagrangian analysis in which the continuous (liquid) phase is treated by solving a system of Eulerian conservation equations, while the discrete (vapor bubble) phase is dealt with by integrating Lagrangian equations of motion. Vapor bubbles of changing size can be accommodated easily by this analysis, and the processes of vapor-bubble formation, growth, coalescence, and collapse can be simulated by including appropriate models. Bubble mass, momentum, and energy-interchange source terms in the Eulerian conservation equations will account for the effects of bubble motion and other bubble processes on the continuous (liquid) phase.

Potential Commercial Applications: The results of this project would apply to the design of liquid rocket engine components.

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*** 196** MSFC
89-1-11.02-2008 NAS8-38454
Heat Transfer in Rocket Engine Combustion Chambers and Regeneratively Cooled Nozzles
Seca, Inc.
3311 Bob Wallace Avenue, Suite 203
Huntsville, AL 35805
Yen-Sen Chen (205-534-2008)

An improved heat transfer analysis for liquid-rocket engine design will be developed. State-of-the-art computational fluid dynamics (CFD) methodology will be used to describe accurately the radiation, combustion, and boundary conditions of the flow field at and within combustion-chamber walls and regeneratively cooled nozzles. While current heat transfer analyses separate the problem into three segments--inviscid flow, boundary layer flow, and structural heat transfer, this project will couple all of these processes into a unified computational tool. The approach will use a CFD analysis that places node points in the flow field

and the structure simultaneously to obtain the required solution. Regenerative cooling will be described with boundary conditions external to the wall. The detail and rigor of this high-speed, turbulent flow analysis and the unique treatment of the wall heating will provide a more accurate thermal analysis of the engine than has been previously possible.

Potential Commercial Applications: This project could be important in designing the next generation of rocket engines, which are expected to utilize gas generator cycles.

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*** 197** MSFC
89-1-11.03-8629C NAS8-38449
Ortho-Para Conversion in Space-Based Hydrogen Dewar Systems
Alabama Cryogenic Engineering, Inc.
P.O. Box 2470
Huntsville, AL 35804
John B. Hendricks (205-536-8629)

A new catalyst configuration will be designed for para-ortho conversion of hydrogen. This endothermic reaction, which can have a significant refrigeration effect, is very important for long-term cryogenic storage of liquid hydrogen on-orbit. This project will investigate suitable catalytic materials, friction-factor and heat-transfer correlations, processing trade studies, and system optimization. The specific innovation lies in the use of a high-thermal-conductivity support for the catalyst material so that the heat of conversion can be efficiently transferred to the appropriate thermal station. In Phase I of the project, a prototype catalytic converter will be designed.

Potential Commercial Applications: This innovation applies to long-term storage of liquid hydrogen.

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*** 198** MSFC
89-1-11.04-6425 NAS8-38459
Slit, Digital Radiography for Analysis of Bond Defects in Rocket Motors
Bio-Imaging Research, Inc.
425 Barclay Boulevard
Lincolnshire, IL 60069
Bruce G. Isaacson (312-634-6425)

This project will determine the feasibility of using slit, digital radiography with high-performance, discrete-element X-ray detectors to evaluate bond-line defects. These detectors, developed for medical computed tomography (CT), are being applied to industrial digital radiography (DR) and CT imaging. Slit radiography, a DR technique, may able to assess bond-line defects in cylindrical assemblies such as solid-rocket motors. This technique can map density variations within the rocket-motor wall associated with matrix-rich areas, cracks, porosity, and voids. The wide dynamic range of the detectors accommodates the multiple-path data collection necessary for CT and allows them to pick up small density differences in materials when used for either DR or CT. Recent improvements also make it possible to resolve the small features of interest in industrial applications. Simulated and actual bond-line defects will be investigated in order to compare the results of the slit radiography with computed tomography and traditional, tangential, film radiography to determine the effectiveness of the innovation.

Potential Commercial Applications: This capability would be useful to aircraft and aerospace component manufacturers.

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199 MSFC
89-1-11.04-8900A NAS8-38444
Physically Based, Failure Criteria for Carbon-Phenolic Materials
PDA Engineering
2975 Redhill Avenue
Costa Mesa, CA 92626
John P. Norman (714-540-8900)

While carbon-phenolic materials have been widely used in solid-rocket motors (SRMs) without thorough understanding of their thermal and structural behavior, their use in the SRMs for the space shuttle requires the capability for accurate analysis, including failure prediction, of these materials. This project addresses this problem through the creation of a physically based failure criterion for carbon-phenolic materials. Based on physical material parameters observed from test data, this failure criterion is different from a purely mathematical "curve fit" criterion, which merely seeks to fit test data. This criterion will separately address three distinct phases of carbon-phenolic behavior throughout its temperature range: the low-temperature, pyrolysis, and high-temperature phases. Within each of these phases, material-failure modes, processing variables, statistical behavior, and critical-size effects will be considered.

Potential Commercial Applications: An accurate, practical failure criterion for carbon-phenolic can increase the performance and reliability of large solid rocket motors and may be applicable to commercial composites applications.

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200 MSFC
89-1-11.04-9964 NAS8-38445
Assessment of Materials in Solid-Rocket Motors by Real-Time CT
Imatron, Inc.
389 Oyster Point Boulevard
South San Francisco, CA 94080
Elan Scheinman (415-583-9964)

This project will adapt the technology of a developed electron-beam, computed tomography scanner to evaluate property changes in materials used in solid-rocket motors. The existing scanner is capable of imaging objects at an acquisition rate of 17 images per second with a resolution of 4 line-pairs per cm. For an acquisition rate of 9 images per second, a resolution of 7 line pairs per cm can be achieved. The scanning times in these two modes are, respectively, 50 and

100 ms. Not only can this scanner evaluate materials in the conventional CT scan modes, but it will scan while materials are being subjected to real-world conditions such as extremes in temperature and/or stress and in real-time.

*Potential Commercial Applications:*Applications could occur in airlines, military contractors, and private companies who are now designing space vehicles.

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201 JPL
89-1-11.06-1759 NAS7-1080
Computer Simulation of Transient Operation of Small, Bipropellant Engines
Ergo-Tech Systems, Inc.
6937 Estepa Drive
Tujunga, CA 91042
Jose E. Chirivella (818-352-1759)

This project will develop a computer simulation that, by modeling the transient operation of the propulsion system, will calculate contaminant properties at the nozzle-exit plane. The intended user for the simulator is the engineer with a background in propulsion. User interface and output management is provided by an expert system. Existing transient codes will be modified, improved, and integrated; a unique feature is that the chamber phenomena are simulated from rarefied regime to steady-state conditions. The simulator can also be employed to develop stability rating criteria and transient performance specifications. Phase I will establish the operational aspects of the simulator and the feasibility of the approach will be demonstrated with two sample cases. In Phase II, the code will be upgraded to simulate three-dimensional two-phase flow, and experimental work will be conducted to verify injector flow dynamics. The transient burning of propellant droplets will be verified in a small vertical shock tube facility.

Potential Commercial Applications: A likely commercial application is in the design, qualification, and selection of bipropellant engines for communication satellites. Future modifications of the code may be extended to simulate air-breathing engines (piston and turbine).

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12: Human Habitability and Biology in Space

* **202** JSC
89-1-12.01-1167 NAS9-18328
Solid-State Neutron Dosimeter for Space Applications
Radiation Monitoring Devices, Inc.
44 Hunt Street
Watertown, MA 02172
Gerald Entine (617-926-1167)

An important contributor to the radiation exposure of personnel engaged in space flight is the flux of high-energy neutrons arising from both primary and secondary sources of ionizing radiation. A suitable, compact neutron sensor that can be incorporated in a flight instrument to provide high-quality, real-time measurement of this important radiation flux does not exist. This project will construct such a neutron sensor using a special PIN silicon diode that has the attractive property of being quite insensitive to the other forms of ionizing radiation which present difficulties to traditional neutron sensors. To achieve this result, research will be conducted on the physics of the diode as well as on specialized electronics capable of reading the diode without perturbing its behavior. The resulting instrument will have the capability of being flight-packaged and readily interfaced with other dosimeters.

Potential Commercial Applications: A compact, accurate personal neutron dosimeter will have application in power plants, accelerator facilities, and industrial facilities using neutron activation analysis or neutron radiography.

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203 JSC
89-1-12.01-1191 NAS9-18316
Transdermal Drug Delivery System for Application in Space Flight
Iomed, Inc.
2320 S. 1290 W., Suite A
Salt Lake City, UT 84108
Thomas J. Petelenz (801-975-1191)

Microgravity and other space flight conditions create new health problems and requirements for new methods of drug delivery. In many instances, medical procedures applicable on Earth are ill-suited to the environment of space, which requires minimum weight and volume, elimination of fluid handling, and ease of operation without specialized training or referral to fully equipped centers. This project addresses the problem of drug administration during space flight. The effort will center on the preliminary development of an iontophoretic system to treat medical conditions occurring in space flight by parenteral delivery of drugs. Specifically, the work will include: determination of the system specifications to integrate with NASA requirements; design of a battery-powered iontophoretic dose controller; synthesis of a polymeric hydrogel matrix to contain the drugs, and fabrication of a model system. Preliminary laboratory characterization will include measurements of drug transport, toxicity, and dermal irritation tests. The final product will be a compact, light-weight system for painless, non-invasive, non-fluidic, controllable delivery of drugs by the parenteral route. To delineate the specifications of the system, three model drugs--fentanyl, gallium, and scopolamine--for treatment of severe pain, bone demineralization, and motion sickness have been selected for the project.

Potential Commercial Applications: An effective system for parenteral drug delivery will have wide application in terrestrial medicine in such areas as post-operative

administration of narcotic agents and treatment of osteoporosis.

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204 JSC
89-1-12.01-7751I NAS9-18314
Selective Enrichment of Stable Calcium Isotopes Using Laser Techniques
Eastern Analytical, Inc.
335 Paint Branch Drive
College Park, MD 20742
Larry J. Moore (301-454-7751)

Scientific efficacy and lack of radiation exposure preferentially commend the use of stable calcium isotopes to study calcium metabolism in astronauts during prolonged space flights. However, their cost and availability are a significant barrier to widespread applicability. Selective enrichment of calcium isotopes using laser techniques offers the potential to eliminate the cost and availability barriers. Recent applications of lasers in atomic physics indicate that modern laser technology may be used to enrich selectively calcium isotopes through one or all of several mechanisms. The purpose of this project is to use selective, laser-resonance, ionization mass spectrometry to demonstrate the feasibility and evaluate the potential for the laser enrichment of stable calcium isotopes. The project will determine efficiencies of two-photon resonance ionization processes; evaluate ionization selectivity and overall enrichment system throughput; and theoretically and experimentally evaluate highly selective isotopic ionization.

Potential Commercial Applications: Availability of the minor calcium stable isotopes at low cost could enlarge an already substantial market. Commercial sales could occur for a variety of biomedical and other applications.

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205 MSFC
89-1-12.02-5201B NAS8-38460
A Reagentless Separator for Removal of Inorganic Carbon from Solution
Umpqua Research Company
P.O. Box 791
Myrtle Creek, OR 97457
Clifford D. Jolly (503-863-5201)

This separator provides a novel method for removal of inorganic carbon from solution prior to organic carbon analysis. It is suited for extended operation in micro-gravity, as it does not require the addition of liquid reagents nor purge gases for inorganic carbon removal. The device consists of a CO_2 permeable-membrane degasser containing a solid-phase acidic material. The device will be designed for integration with prototype, flight water-quality-monitor hardware. The device functions to remove dissolved gas from sample streams prior to analysis using IR, UV, and other methods of detection.

Potential Commercial Applications: The separator is suitable for use in industrial analytical instrumentation, particularly that used in remote or inaccessible locations.

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206 MSFC
89-1-12.02-5615 NAS8-38439
Incipient Combustion Monitor for Zero-Gravity Environments
Ada Technologies, Inc.
304 Inverness Way South, Suite 480
Englewood, CO 80112
James A. Armstrong (303-792-5615)

This project investigates a dynamic-expansion, condensation-nuclei chamber for the detection of sub-micrometer particles emitted when combustible materials are heated. Such a device would be employed as the sensor of an incipient combustion monitor for use on the NASA space station. Combustible materials expected to be used in the construction of the space station will be tested in a proof-of-concept laboratory system to confirm the generation of sub-micrometer particles when heated. A Gardner condensation-nuclei counter will be used as the dynamic expansion chamber. A computer model of the operation of dynamic expansion chambers in terrestrial and zero gravity environments will be used to identify differences in the operation of this system in space. A preliminary design for a prototype monitor will be prepared. The prototype would be tested in Phase II of the project.

Potential Commercial Applications: This device would provide early warning of imminent fire where the natural sub-micrometer particle count was very low so that an alarm could be sounded at a low signal-to-noise ratio. It could also determine the presence of sub-micrometer particles in clean room environments.

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*** 207** MSFC
89-1-12.02-6706 NAS8-38470
Thin Membrane Sensors
Resource Technologies Group, Inc.
400 Mississippi Street
Morgantown, WV 26505-6751
George D. Case (304-291-6706)

Thin-film-membrane-based sensors and components offer potential for very high (up to $1O^{12}$) amplification gain and dime-sized dimensions, with specificity for biological processes and agents. Examples are microbial pathogens in water or media, infective agents or food spoilage indication, plant pathogens, allergens, drugs, or hormones. Detection at unit agent levels appears feasible on a near real-time basis. At the heart of the sensor are a thin membrane and an electrochemical switch. Phase I focusses on improving the properties of the membrane to permit an electrically active and mechanically stable sensor to be fabricated. Subsequent work under Phase II would incorporate the membrane into an electronic readout system for a working prototype.

Potential Commercial Applications: Thin membrane sensors can be adapted for use as a rapid screening

tool for a host of chemical and biological agents, such as viruses, bacteria, and toxins in medical or pharmaceutical operations, food processing, quality control for monoclonal antibody production, and health care products.

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*** 208** JSC
89-1-12.03-4131 NAS9-18317
Solid-Polymer, Electrolyte-Based Electrolyzers for Water Reclamation Post-Treatment
Lynntech, Inc.
111 E. 27th Street, #204
Bryan, TX 77803
Ramesh C. Kainthla (409-846-4131)

On long-duration space missions, water reclaimed from urine, humidity condensate, and hygiene water will be contaminated with organic chemicals and microorganisms. One means of completely eliminating microorganisms and total organic carbon is to treat contaminated water with ozone and hydrogen peroxide together. Both these oxidants react rapidly in water, and simple procedures can ensure that these reagents are broken down to water and oxygen. A solid-polyerelectrolyte (SPE) electrolyzer unit will be constructed that generates O_3 and H_2O_2 directly in the water stream. No expendable materials other than small quantities of air will be required. A solid polymer electrolyte avoids the difficulty of separating the oxidants produced from the electrolyte. Electrochemical technology for the anodic generation of O_3 and for the cathodic generation of H_2O_2 is well established. The aim of this work is to construct a novel SPE electrolyzer that combines both of these reactions.

Potential Commercial Applications: Markets for devices providing ultra-pure, sterile water exist in the electronics and pharmaceutical industries and for providing high-purity sterile water for hospitals at reduced costs.

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*** 209** JSC
89-1-12.03-5201 NAS9-18336
Electrochemical Water Recovery Process for Direct Removal of Impurities
Umpqua Research Company
P.O. Box 791
Myrtle Creek, OR 97457
David F. Putnam (503-863-5201)

In this concept for water reclamation in space, organic impurities are removed by electrolysis; inorganic impurities by electrodialysis. In previous reclamation work, a problem was caused by the relative insolubility of potassium perchlorate, which precipitated within the electrodialysis membranes causing them to cease functioning. Efforts to overcome the problem by preventing the formation of perchlorates in the electrolysis step were unsuccessful. In this project a regenerable cation exchange resin bed will remove the trouble-some potassium ions and replace them with sodium ions, which form a more soluble perchlorate salt. Regeneration will be achieved with the concentrated sodium-rich brine from the electrodialysis step. No expendable materials will be required.

Potential Commercial Applications: This process would be useful in sewage treatment for boats and ships and treatment of toxic organic wastes.

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*** 210** ARC
89-1-12.04-8450B NAS2-13168
Methodologies for Processing Plant Materials into Acceptable Food on a Small Scale
Food and Agrosystems, Inc.
P.O. Box 62185
Sunnyvale, CA 94088
Thomas R. Parks (408-245-8450)

This project investigates processes for the direct and/or indirect use of plant fractions that are not used as food for astronauts. These fractions may improve nutritional balance by increasing fiber intake. Data on stem, leaf, and root material from crops such as soybeans, wheat, and potato will be examined to assess potential nutritional contribution, functional properties, and undesirable features such as off-flavors, flatulence production, and toxic reactions. Processes considered may include enzyme digestion, extraction, hydrolysis, and fermentation as well as physical treatments such as heating, steam-stripping, and dehydration. The project will evaluate the potential to improve acceptance, digestibility, functional properties, nutritional value, and versatility. For selected processes, preliminary estimates would be made of equipment, energy, and space requirements. The Phase I report will discuss the processes and products considered, with emphasis on those processes appearing most promising. Laboratory evaluation of selected processes and products would be carried out in Phase II.

Potential Commercial Applications: Given the growing public interest in high-fiber dietary supplements, new technologies providing additional low-cost sources of fiber could find ready acceptance in a wide range of food products.

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211 JSC
89-1-12.05-1400 NAS9-18311
Capturing Space Crew Representations of Control Systems with Multi-Dimensional Scaling
Chi Systems, Inc.
Gwynedd Plaza III
Spring House, PA 19477
Wayne W. Zachary (215-542-1400)

The complexity of spacecraft in-flight operational systems has led to the need to support system operators with intelligent technologies. Modeling the operator's cognitive processes is necessary for the development of these technologies. The project will employ an innovative tool and methodology based on multi-dimensional scaling (MDS) for capturing the cognitive structures of space-crew operators. This

methodology is innovative because, unlike existing techniques, it is quantitative, formal, and replicable, and it accesses the underlying structure of an operator's conceptual representation. Existing knowledge elicitation tools, in contrast, are qualitative and heuristic; focus only on an operator's procedural knowledge; and can be more useful in unanticipated operational conditions. An automated, knowledge-acquisition, MDS-based shell will be developed in Phase II, based on the design and techniques developed in Phase I.

Potential Commercial Applications: Automated, knowledge-acquisition tools would apply in expert systems development, operator-system interface development, and training system design.

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*** 212** JSC
89-1-12.05-2040 NAS9-18320
Optimal Workspace Design
MOCO, Inc.
P.O. Box A
Scituate, MA 02055-0974
Ruth A. Maulucci (617-545-2040)

The objectives of this project are to implement and verify an optimal control model of guided limb motion and to use this model to develop a software system for the design of workspaces that are optimal for human performance and productivity. The system will apply to normal, reduced-G, and zero-G environments and will facilitate the layout of spacecraft interiors for operating instruments, recreation, and daily living activities. The innovative features of this project are the model's realistic representation of functional reaching and the application of optimal control software to workspace design. The model will represent the dynamics for three-dimensional, out-of-plane reaching for targets in multiple locations and under varying conditions and will include plausible performance criteria. The software system for workspace design will be developed as an interactive and parameterized structure and will produce analytic and graphic results.

Potential Commercial Applications: This software system could apply to the design of vehicle interiors, instrument panels, man-machine interfaces, and factory layouts. The system may also have application in the robotics field as a design tool and in the rehabilitation field as an arm trajectory retraining device.

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213 ARC
89-1-12.05-9275 NAS2-13159
Performance of Groups In Extreme Environments: a Meta-Analytic Integration
Florida Maxima Corporation
2180 Forrest Road
Winter Park, FL 32789
James E. Driskell (407-644-9275)

With future NASA missions characterized by longer flight durations, increased crew size, and greater crew heterogeneity, managing the human component of the flight system becomes an even more critical task. A vast amount of research has been performed since the 1950's examining human performance in exotic environments, producing valuable yet often seemingly conflicting results that are difficult to integrate at the narrative level. This project takes a unique and innovative approach, using a meta-analytic statistical technique, to analyze, compare, and integrate research on performance in exotic environments. The results of this work will provide specific data on those variables that have been suggested or conjectured to be critical to effective performance in the exotic space environment. It will also identify and uncover factors that moderate the negative effects of isolation, confinement, and risk. This data will provide practical and reliable guidelines for the effective management of flight crews on future space missions.

Potential Commercial Applications: Practical specifications and guidelines for selection, training, and human factors design of exotic environments are directly applicable to commercial entities that perform crucial tasks in stressor environments including commercial aviation, the nuclear industry, and the petrochemical industry.

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*** 214** JSC
89-1-12.06-8100 NAS9-18305
Automation of Stowage
Aptek, Inc.
1257 Lake Plaza Drive
Colorado Springs, CO 80906-3578
Jerry L. Udy (719-576-8100)

This project will determine optimal packing solutions for location and orientation of items to be stowed in the space station using three-dimensional computer graphics coupled with engineering design optimization methodologies. Constraints such as minimum distance between objects, mass properties, fixed object orientation, object layering, and stowage container designation will be addressed. The project will examine the feasibility of interfacing the optimal packing capability with NASA/Air Force laser mapping system to provide an efficient method of modeling extremely complex objects to be stowed and with numerically controlled machining equipment to allow automatic machining of packing material. This evolutionary innovation will improve and link together existing capabilities to provide NASA with an imaginative, low-risk, automated solution to the difficult space station stowage problem.

Potential Commercial Applications: The automobile, aerospace, electronics, and shipping industries could benefit from technology to place three-dimensional objects optimally into containers (or space).

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*** 215** JSC
89-1-12.06-8961 NAS9-18324
Charge-Coupled Device Sensors for Electronic Still Photography
Photometrics Limited
3440 E. Britannia Drive, #200
Tucson, AZ 85706-5006
Gary R. Sims (602-623-8961)

A need has been identified for an electronic still camera for space flight applications that incorporates a suitable solid-state electronic imaging detector. In this project, the key performance specifications concerning the detector--including optical sensitivity, spatial resolution, readout rate, dynamic range, dark current, and spatial crosstalk--will be identified. A number of experiments and tests will be performed to determine the optimal combination of charge-coupled-device (CCD) and CCD readout and signal processing technologies to produce a detector suited for electronic still photography applications. These include evaluation of CCD transport register architectures and approaches to increasing sensitivity to blue/visible wavelengths; testing noise and noise spectral characteristics of various output amplifier design approaches; evaluations of high-speed CCD double-correlated signal processing circuits; and evaluation of the feasibility of employing multiple CCD output ports.

Potential Commercial Applications: Applications include space-borne and ground-based still electronic photography, surveillance, optical microscopy, low light level underwater imaging.

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*** 216** JSC
89-1-12.07-0559A NAS9-18330
Using Robots in Testing NASA EVA Space Suits
Sarcos Research Corporation
261 E. 300 South, Suite 150
Salt Lake City, UT 84111
Fraser M. Smith (801-531-0560)

The company and the Center for Engineering Design at the University of Utah have developed and commercialized humanoid robots with remarkably human-like motions for the entertainment industry. With a new computer-based program controller and data acquisition system, this project will develop a humanoid robot into a space-suit tester. It will be able to perform life-cycle tests and to measure mobility and range of motion of NASA EVA space suits. This will provide a safe, economical, repeatable and accurate means to test space suits, aiding in the design of reusable space suits and assisting in quality assurance tests. Phase I will include the feasibility study, conceptual design, and definition of a space-suit testing program using robots. Phase II would produce the definitive design and the construction and testing of a functional robot and control system.

Potential Commercial Applications: Computer-controlled, articulated mannequins could be used by designers and manufacturers of protective clothing and equipment for hostile environments including nuclear, space, high-pressure, and hazardous chemical.

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217 JSC
89-1-12.07-4100A NAS9-18309
Membrane-Based, High-Pressure Gas-Dehydration Module
Bend Research, Inc.
64550 Research Road
Bend, OR 97701-8599
Roderick J. Ray (503-382-4100)

NASA is developing water-electrolysis cells to recharge the Extravehicular Mobility Unit (EMU) oxygen bottles in flight. These cells produce high-pressure (up to 6000-psi) oxygen and hydrogen streams saturated with water vapor. These gas streams must be dehydrated to very low water-content levels--typically at least to -70°F dew-point temperature--to prevent valves from freezing or tanks and lines from becoming contaminated. A new type of membrane module can dehydrate these gas streams at pressure using no moving parts or external power. The driving force for dehydration is provided by allowing a small percentage of the feed gas to permeate the membrane. Preliminary tests and calculations indicate that this new module will have low mass and be compact; will require only about one percent of the feed gas for operation; and involve virtually no maintenance due to its simplicity.

Potential Commercial Applications: A membrane module capable of dehydrating high-pressure gas-feed streams would have numerous commercial applications in the production of high-quality, specialized compressed gases for radar waveguides, specialty-instruments, and various defense applications.

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218 JSC
89-1-12.08-5201 NAS9-18337
Thermally Desorbable Toxin and Odor Control Cartridge
Umpqua Research Company
P.O. Box 791
Myrtle Creek, OR 97457
Gerald V. Colombo (503-863-5201)

A number of space station systems utilize air streams for transportion of materials or for ventilation. A light-weight, low-power, regenerable air purification system is needed for the removal of trace contaminants before these streams are returned to the cabin. These contaminants include a wide range of organic compounds, that are artifacts of human metabolism. Specific regenerable sorbents have been identified which effectively remove these potential contaminants from gaseous streams by adsorption at ambient temperatures and desorb these compounds with high efficiency at elevated temperature. The sorption-thermal-desorption phenomenon provides the basis for the development of a regenerable, trace-contaminant removal system.

Potential Commercial Applications: Regenerable air purification systems would apply in the control of industrial emissions and in home air-conditioning systems.

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*** 219** JSC
89-1-12.08-9357 NAS9-18321
Device for Sample Collection and Rapid Immunological Identification of Biological Specimens
New Horizons Diagnostics
9110 Red Branch Rd
Columbia, MD 21045
David Bernstein (301-992-9357)

This project is developing a self-contained, solid-phase, colorimetric immunoassay for the rapid identification of biological analytes for use in a micro-gravity environment. The patented technology for this simple-to-use, non-instrumented device can detect as few as 2×10^3 Group A streptococci in less than 5 minutes. For use in space, the design concept is a single-use tube which has a dacron swab for sample collection, a series of chambers containing lyophilized extraction and colloidal gold immuno-reagents, a reconstitution buffer, and a reaction zone on a fixed membrane. After using the swab to collect a biological specimen, it is returned to the device and pushed through the reagent chambers. After one to five minutes, the swab is pushed further into the tube device where the reactants diffuse for at least one minute into a capture membrane. The membrane is then observed with the naked eye for the presence of an analyte indicated by development of a red spot. This device is ideal for use in space: all transfer of reactants is accomplished by movement of the swab and diffusion; no washing, additional steps, or reagents are required; each single-use test can be stored at room temperature; and the device is designed for use by untrained personnel.

Potential Commercial Applications: This technology can be utilized for diagnostic purposes by untrained personnel for physicians' offices, homes, third-world countries, space travel, the military, and environmental testing.

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*** 220** MSFC
89-1-12.09-0966 NAS8-38446
Chemical Sensor System for the Identification of Organic Compounds in Water
Boston Advanced Technologies, Inc.
656 Beacon Street
Boston, MA 02215
Edward Sinofsky (617-267-1545)

An innovative, field-deployable system for detection and identification of organic chemical pollutants in water sources is the goal of this project. The system will utilize laser Raman light scattering as the spectroscopic sensor forming the core of the approach and will employ surface-enhanced Raman scattering combined with fiber-optic collection of the enhanced scattered light signal in its sampling system to augment the normally low-intensity Raman scattering signal from trace materials.

Potential Commercial Applications: A fiber-optic sensor capable of detecting and identifying low levels of organic pollutants in water sources on site would be useful to industries and agencies concerned with water quality.

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221 ARC
89-1-12.11-3309 NAS2-13167
Automated Food Delivery to Rodents in Space
Star Enterprises, Inc.
P.O. Box 1748
Bloomington, IN 47402
Jeffrey R. Alberts (812-855-3309)

The goal of this project is to provide flight hardware for rodents that will collect and store accurate data on food consumption. The approach to hardware design considers the test animals to be part of the design team by incorporating animal testing throughout conceptual design and model-building. Rodents' food-handling and ingestion patterns will be related to diet type and food form. Mode of delivery will be designed to maximize efficient eating and minimize loss and wastage. Feeding systems also involve attention to waste products such as loose particles, as well as urine and feces production. Metabolic output will be measured in relation to different diets. The project will culminate with the fabrication of at least three functional models of innovative feeding systems capable of maintaining rodents during long-duration flights and providing accurately measurable quantities of diet. They will be serviceable without opening the animal habitat.

Potential Commercial Applications: Commercial ventures interested in developing life sciences payloads involving animals will need hardware systems similar to those to be developed in this project. Likely users include the pharmaceutical industry, genetics researchers, and various biomedical interests.

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*** 222** KSC
89-1-12.12-6700 NAS10-11657
Remote Moisture Sensor to Control Irrigation of Plants in Space
Axiomatics Corp.
60 Rogers Street
Cambridge, MA 02142
James F. Bredt (617-497-6700)

The objective of this project is a remote moisture sensor for an automated irrigation system that maintains a thin layer of nutrient solution on a surface occupied by the roots of plants growing in space. Electrically isolated from the root system, the sensor is laminated into the surface and measures the thickness of the nutrient layer. The technical problems attending the growth of plants in space require some form of irrigation control, and this project should provide a degree of accuracy unobtainable by other methods.

The sensor operates by continuously measuring the dielectric properties of material adjacent to the sensor. The high-frequency response of the sensor is correlated to a database that is programmed into the software of the monitor. The versatility of this technique allows for the possibility of measuring other process variables in addition to the moisture content of the plant-growth surface.

Potential Commercial Applications: A device for sensing moisture could apply to control of irrigation and other agricultural processes on Earth. A thin-layer sensor could have applications in non-destructive testing in a wide variety of fields, including composite engineering and semiconductor processing.

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223 KSC
89-1-12.12-7070 NAS10-11652
Trace-Contaminant Vapor Monitors
Geo Centers, Inc.
7 Wells Avenue
Newton Centre, MA 02159
Mary Elizabeth Tabacco (617-964-7070)

The goal of this project is to design and evaluate optrodes to monitor trace-contaminant vapors present in NASA's Biomass Production Chamber. The target species will be either ethylene or carbon monoxide. The approach utilizes two types of porous fiber waveguides combined with selective chemistry. These novel optrodes offer high sensitivity, design flexibility, and the inherent fiber-optic advantages of immunity to electromagnetic interference, small size, ruggedness, and freedom from explosion hazard. Subsequent to laboratory evaluation, a sensor design will be recommended for Phase II development and field testing at the Kennedy Space Center.

Potential Commercial Applications: An ethylene sensor would be used for inexpensive, low-level detection of ethylene vapor for commercial hydroponic and aquaculture ventures, and, at higher levels, accurate monitoring in the plastics and welding industries. Carbon monoxide vapor monitors are also needed. The technical approach could be applied to sensing requirements for other contaminants.

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* **224** KSC
89-1-12.12-7653 NAS10-11656
Fiber Fluorometry for On-Line Chemical Analysis of Nutrient Solutions
Biotronics Technologies, Inc.
12020 West Ripley Avenue
Wauwatosa, WI 53226
Kenneth J. Schlager (414-475-7653)

This project will explore the feasibility of on-line measurement of ionic nutrients such as potassium, magnesium, and nitrates used in hydroponic plant growing facilities. It will employ the BI-401 Fiber Fluorometric Analyzer developed by the company and applied initially for analytes with native (primary) fluorescence as in aromatic compounds and fermentation control. Ionic concentration measurements will require the use of an optrode (probe) coated with various immobilized chelate reagents that vary in secondary fluorescence intensity with ionic concentrations. The interaction between the chelate reagent and the target ion will generate fluorescence with an intensity that is proportional to ion concentration.

Potential Commercial Applications: An on-line, fluorometric ion analyzer would apply in real-time monitoring of wastewater trace-metal pollutants such as cadmium, chromium, or lead. The fluorometric analyzer would also have direct application in commercial hydroponic greenhouse operations.

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225 KSC
89-1-12.14-5668A NAS10-11650
Anatomical Image Analysis Techniques
Numedloc
430 Hollybush Rd
Bryn Mawr, PA 19010
Lon Crosby (215-527-4995)

Biostereometrics is the analysis of biological form or function based on principles of analytic geometry. This technique defines the surface of an object by a finite set of three-dimensional coordinates generated from the analysis of pairs of two-dimensional images. Coordinates can be manipulated to determine body surface area, volume of specific parts or the whole, lengths, breadths, etc. The comparison of data over time also allows changes to be monitored: motion analysis for very short time periods and growth or degradation for longer periods. This project will develop an automated, computerized, image analysis system that will reduce the costs and improve utility over existing manual systems. The data collection system will use commercially available hardware and include: an MS-DOS computer, a RISC processor optimized for FORTH operation, four CCD/MOS video cameras, a four-channel frame grabber, a video display, data storage device(s), and dedicated data processing enhancements. Software routines will be developed to meet specific needs.

Potential Commercial Applications: Biostereometric systems can monitor growth and development; determine body composition when residual gas volumes are independently determined; monitor induced tissue catabolism; evaluate and visualize plastic and reconstructive surgery; develop molds for prosthetic devices; and analyze motion and range of motion.

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13: Quality Assurance, Safety and Check-Out for Ground and Space Operations

226 KSC
89-1-13.01-6239 NAS10-11651
A Real-Time, Particle Fall-Out Monitor
Femtometrics
1721 Whittier Avenue, Suite A
Costa Mesa, CA 92627
W. D. Bowers (714-722-6239)

This project investigates an advanced approach for the measurement of particle fall-out contamination in real time: the elutriator, quartz-crystal microbalance (EQCM). It will replace tedious, time-consuming methods that involve collection and manual counting of fall-out particles captured in filters or plates. The EQCM instrument will separate airborne particles according to specific, selected cut-off sizes; collect and weigh the particles in real time on a sensitive microbalance; and retain the collected particles for post analysis by optical or electron microscopy. The high mass-sensitivity of the EQCM allows detection of a single, 25-micron particle of mass density 2 g/cm^3.

Potential Commercial Applications: This particle fallout monitor would be valuable to the aerospace and microelectronic industries to monitor critical surfaces for contamination. The textile industry could also use it to monitor the levels of respirable particles.

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227 KSC
89-1-13.02-4256 NAS10-11654
A Repair Coating for Cryogenic Transfer Lines
TPL, Inc.
3754 Hawkins NE
Albuquerque, NM 87109
Larry A. Harrah (505-345-5668)

This project explores a method to repair leaks in the vacuum jackets of transfer lines for cryogenic fluids. An in-place repair process is desired, and repairs cannot rely on conventional adhesive mechanisms. A ceramic coating will be used as a repair material. In-place formation will be achieved through sol-gel processing. Adhesion is obtained through mechanical forces and strong chemical bond formation. Ceramic properties will be tailored through selective use of alkoxide precursors to match substrate properties and operational environments. A ceramic-patch coating will be formulated, and the ability to tailor ceramic properties to match substrate properties will be demonstrated. Adherence of the coating to the substrate through environmental cycling will be investigated.

Potential Commercial Applications: The techniques developed in this project will advance sol-gel technology for such applications as high-purity, high-fineness powders, lubricants, and ceramic supports.

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*** 228** KSC
89-1-13.03-1512 NAS10-11655
A Novel Laser System for Forecasting and Mitigating Lightning Strikes
Ophir Corporation
3190 S. Wadsworth Boulevard, Suite 100
Lakewood, CO 80227
Gregory J. Fetzer (303-986-1512)

The goal of this project is to apply a high-energy, pulsed laser to ionize a preferential path through the atmosphere along which lightning would travel. This capability would provide lightning protection, forecasting, and/or mitigation at the shuttle launch site. A high-energy, pulsed, UV laser operating at a wavelength never before used would be used to multi-photon ionize trace atmospheric constituents to trigger lightning strikes down the laser-ionized path. This device could be used to forecast the probability of lightning strikes during vehicle launch and, perhaps, to mitigate that probability by harmlessly and repetitively discharging the atmosphere and thereby protecting the launch vehicle. Phase I will involve two distinct parts: first, specification of a laboratory system for verifying the feasibility of a laser lightning rod and, second, extension of a laser-atmosphere model to simulate the experiments which might be carried out during Phase II.

Potential Commercial Applications: This project would provide lightning protection, forecasting and/or mitigation on a scale never before possible.

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229 MSFC
89-1-13.03-1982 NAS8-38465
Instrumented-Rocket Wind Profiler
FWG Associates, Inc.
217 Lakewood Drive
Tullahoma, TN 37388
S. Leon Felkins (615-455-1982)

This project will apply advanced technology to develop an inexpensive, instrumented rocket for measuring wind profiles in support of aerospace vehicle (STS) operations. The goal is a system that will allow measurement of winds close to the scheduled launch time and along the launch path. This would reduce the uncertainty margin of calculated wind loads, increase launch probability (7 to 8 percent), and decrease the risk of launching under adverse wind conditions. Shuttle pre-launch winds are typically measured with slow-rising Jimsphere balloons released some 3.5 hours before launch; these can drift miles on a day of strong winds. Accurate wind profiles can be obtained with an instrumented aircraft in approximately 10 minutes, albeit at high cost. A small, instrumented rocket can be directed specifically along the shuttle launch path to measure wind-speeds well within the desired 10-minute time frame.

Potential Commercial Applications: The wind profiler could be applied in STS, commercial launch vehicles, USAF unmanned aerospace vehicles, and military operations on land or sea. It could also be applied in

determining NASP high-altitude wind-profile requirements and EOS ground-truth for remote areas.

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*** 230** KSC
89-1-13.03-4122 NAS10-11660
Meteorological Monitoring System
ENSCO, Inc.
5400 Port Royal Road
Springfield, VA 22151
Gregory E. Taylor (407-254-4122)

The goal of this project is automated, real-time monitoring of critical weather elements for use by NASA managers and the forecasters at the Cape Canaveral Forecast Facility (CCFF). This meteorological monitoring system (MMS) would provide for timely issuance of weather warnings and advisories for protection of lives and property at Kennedy Space Center. It would also monitor the weather versus constraints during launch operations at KSC and Cape Canaveral Air Force Station. The MMS will continuously monitor and review data from the weather sensors at the launch sites, alert the operator to potential hazards or trends in the data, and sound an alarm when a weather threshold is exceeded. The MMS will not introduce a new screen for the CCFF forecasters to monitor; rather, it will be integrated with the existing Meteorological and Range Safety Support System. A side benefit of the MMS will be a reduction in data overload problems experienced by forecasters.

Potential Commercial Applications: Designed to accept data from the meteorological sensors in use today, this system could be used at most Air Force test ranges, and it could serve as a developmental system for major airports for monitoring winds, radars, wind-shear sensors, and lightning detection equipment.

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*** 231** KSC
89-1-13.04-2888 NAS10-11653
Supercritical, Cryogenic, Self-Contained Breathing Apparatus
Aerospace Design & Development, Inc.
P.O. Box 672
Niwot, CO 80544
H. L. Gier (303-530-2888)

The purpose of this project is the development of a self-contained, breathing apparatus (SCBA) based on the use of supercritical, cryogenic liquid air in place of a two-phase, liquid-vapor system. The supercritical liquid air will be stored at about 50 atmospheres, well above the critical pressure for air (37 atmospheres). In this condition, single-phase air is available at a single, fixed outlet independent of tank attitude. Except for a slight possibility of stratification, there will be no selective venting of the nitrogen as happens with two-phase liquid air, and oxygen enrichment is not required. Phase I will investigate fluid properties, including stratification; SCBA weight and volume requirements; system operation; and the refill system. Phase II would design and produce an operating system that would meet OSHA and NISOH requirements.

Potential Commercial Applications: This breathing apparatus would have applications for all fire departments and rescue units currently using high-pressure, gaseous air systems because the operating pressure would be less and the effective lifetime longer.

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232 JSC
89-1-13.06-9500 NAS9-18302
Temperature and Shock-Position Sensor for High-Pressure, Oxygen Systems
Aerodyne Research, Inc.
45 Manning Road
Billerica, MA 01821
Kurt D. Annen (508-663-9500)

Sensors will be developed to investigate the causes of impact-initiated ignition in high-pressure oxygen lines. This problem arises due to the adiabatic compression of the residual oxygen in a line when it is opened to the high-pressure oxygen source. A non-intrusive, Rayleigh scattering technique will be applied to measure the temperature at a rate that can resolve the adiabatic compression process. This sensor would be located in an end cap having the same diameter as the oxygen line to avoid discontinuities in area. Based upon the measurement of changes in oxygen density by the change in magnetic permeability, the new sensor will determine the shock velocity and location from which the temperature distribution in the line can be determined. Phase I will consist of a laboratory demonstration of the Rayleigh scattering measurements in high-pressure lines, an analytical modeling effort that approximately describes the compression processes, and the preliminary design of the Rayleigh scattering and shock position sensors.

Potential Commercial Applications: The oxygen density measurement technique may provide a means of non-invasive monitoring of oxygen content or contamination of gases.

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*** 233** JPL
89-1-13.07-7780 NAS7-1083
Automated Assessment of VLSI Circuits for Radiation Hardness and Reliability
Advanced Research and Applications Corp.
425 Lakeside Drive
Sunnyvale, CA 94086-4701
Leslie J. Palkuti (408-733-7780)

This project will develop an automated test method to extract CMOS VLSI circuit parameters to assess hot-electron reliability and radiation hardness. The instrument, when combined with standardized test chips, would be uniquely suited for qualification of low-volume ASIC circuits for space-borne applications. This concept includes the development of automated transfer of test devices between X-ray irradiation, time-temperature annealing, and electrical testing-stations under electrical bias. In addition, the project will

address the testing throughput needed to achieve a low-cost qualification process.

Potential Commercial Applications: A simplified qualification procedure for low-volume ASIC circuits could provide low-cost and quick-turnaround qualification and process monitoring for high-reliability, radiation-hard VLSI circuits for space-borne applications.

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14: Satellite and Space Systems Communications

234 JSC
89-1-14.01-0760A NAS9-18332
Power- and Bandwidth-Efficient Digital Communications
SCS Telecom, Inc.
107 Haven Avenue
Port Washington, NY 11050
Gary Lomp (516-883-0760)

Existing digital radio systems--employing continuous-phase, frequency-modulation (CP-FM) techniques with coherent detection--trade spectral efficiency for low bit-error rate and are subject to degradation due to multipath in certain applications. This project will apply trellis coding of the signal space with CP-FM using PLL demodulation for both symmetrical and asymmetrical signal constellations. System performance will be investigated in the presence of fading, multipath, Doppler interference, and narrowband filtering of the FM signal. These effects cause nonlinear distortion of the modulation and tend to close the "eye" of the demodulated data. Initial research indicates that a nonlinear adaptive equalizer can be used to open the "eye". Finally, an optimum modulation scheme will be selected for a given code rate. The result of this work could be more efficient communications systems for the space station. The advantages of these communication systems will be lower power for the same HER; reduced weight; higher reliability; improved spectral efficiency to reduce cost and adjacent channel interference; better multipath performance; and lower cost.

Potential Commercial Applications: There would be markets in satellite and mobile telephone systems as well as high-data-rate cable systems and in military systems requiring a low probability of intercept.

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235 JSC
89-1-14.01-3100 NAS9-18322
An Electro-Optic Modulator for Laser Wavefront Correction and Positioning In Space
Optron Systems, Inc.
3 Preston Court
Bedford, MA 01730
Ira Farber (617-275-3100)

Laser systems for space-based communication applications are needed for future spacecraft. This project addresses pointing, correcting, and focusing a laser beam in order to meet stringent mission requirements for satellite communications under a dynamic operating environment. The fine-pointing and jitter-control requirements of these advanced communications systems present serious challenges in acquisition, tracking, and pointing. The objective is an adaptive optical, computer-controlled, electro-optic phase modulator for an active optical component with no moving parts that is capable of microradian pointing accuracy. Under software control, this electro-optical device would be used to deflect, focus, collimate, reshape, or otherwise modulate a coherent beam of light. With the addition of a wavefront sensor and a feedback path, the modulator could be incorporated into closed-loop systems for such purposes as automatic wavefront correction, automatic focusing, and target tracking. Phase I objectives include construction and evaluation of a prototype electro-optic modulator. Phase II would address specific issues of optimization.

Potential Commercial Applications: The product of this project could be used in space-based laser communications control of laser propagation through turbulent media.

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*** 236** JSC
89-1-14.01-6642 NAS9-18319
Monolithic, Gallium-Arsenide, UHF-IF, Switch Matrix for Space Station Applications
Microwave Monolithics, Inc.
465 East Easy Street, Unit F
Simi Valley, CA 93065
Daniel R. Ch'en (805-584-6642)

The space station multiple-access communication system will provide the primary telemetry, voice, and video link between crew members and extravehicular astronauts. The heart of this system--which is based on a frequency-division, multiple-access (FDMA) signal distribution system with multiple directional antennas on both the space station and the astronaut(s)--is the intermediate frequency (IF) switch matrix that dynamically routes multiple, wideband signals to the intended destination. In Phase I, the company will design a space-qualifiable, 4 X 8 (or TBD size) monolithic GaAs switch-matrix, its control interface, and an integral hermetic package to satisfy this demanding requirement. The full-scale, prototype UHF-IF switch-matrix would then be fabricated, characterized, and delivered to NASA in Phase II. This reliable, high-performance matrix will be smaller, lighter, and consume less prime power than all currently envisioned alternatives.

Potential Commercial Applications: The design and fabrication techniques of this project will be directly applicable to the rapid development and application of diverse complex, commercial switching systems.

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237 GSFC
89-1-14.02-0211 NAS5-30842
Surface-Acoustic-Wave, Spectral Limiter for Narrow-Band Interference Suppression
Phonon Corporation
7 Herman Drive, P.O. Box 549
Simsbury, CT 06070
Clement Valerio (203-651-0211)

Many wideband communications, radar, and EN receivers could benefit from a simple means of narrow-band (i.e., an order of magnitude less than the desired signal's spectral bandwidth) interference suppression. Surface acoustic waves (SAW) offer such a capability because they can sort frequencies into multiple spatial channels and independently saturate any channel in the presence of a large signal. The device is monolithic, simple, small, passive, two-port, and potentially low cost. The company will build a SAW spectral limiter on lithium-niobate using low-loss transducers with 300 MHz center frequency, 75 MHz bandwidth, at least ten effective limiting sub-channels, and at least 10 dB of interference suppression. Since suppression can be multiplied by cascading devices, ways to maximize suppression will be determined through analysis and experiments. Two prototypes will be delivered.

Potential Commercial Applications: A SAW spectral limiter would be applicable to any wideband system receiver susceptible to narrow-band interference.

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*** 238** GSFC
89-1-14.02-7606 NAS5-30859
High-Speed, Digital Data Transmission
Galaxy Microsystems, Inc.
10711 Burnet Rd Suite 325
Austin, TX 78758
Robert E. Fosdick (512-836-7606)

Use of laser technology for high speed data transmission between next-generation spacecraft requires new circuit technology and data recovery techniques to support the higher bit rates. This project designs the clock and data recovery circuitry for the case where the reference clock is operating at the data rate rather than a multiple of the data rate. The circuitry will use gallium-arsenide technology and offer an operational data rate in the 1 to 2 gigabit per second range. Design criteria for data coding techniques will include transmission power, reference clock rate with respect to data rate, tolerance to jitter, error detection and correction techniques, worst case synchronization time, implementation complexity, etc. Manchester and QPPM coding of the data will be evaluated. GaAs is the device technology recommended because of its superior speed-power product, tolerance to radiation effects, and high speed operation.

Potential Commercial Applications: The techniques for high-bit-rate data synchronization will also be applicable for next-generation telephone transmission systems, digital television, and optical disks. Very-high-speed serial data transfer using laser technology may well be the best solution for the bus interconnect of large, parallel-processor systems.

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*** 239** JPL
89-1-14.04-6642 NAS7-1098
Advanced Monolithic, Gallium Arsenide Receiver Front-End for Spacecraft Transponders
Microwave Monolithics, Inc.
465 East Easy Street, Unit F
Simi Valley, CA 93065
Wendell C. Petersen (805-584-6642)

An advanced X-band GaAs MMIC receiver front-end for spacecraft transponder applications will be developed. This component will consist of three GaAs MMIC chips: a low noise amplifier, a mixer/IF amplifier, and a voltage controlled dielectric stabilized oscillator with on-chip microwave frequency-division circuitry. A hybrid first stage, possibly utilizing pseudomorphic HEMT device(s), would be used to set the overall receiver noise figure. The project draws considerable benefits from technologies previously developed internally and under related NASA-supported programs at the firm. Feasibility will be demonstrated in Phase I via the design and analysis of all three MMIC components. Fabrication, characterization, optimization, and delivery of a breadboard receiver front-end would then follow in a low-risk Phase II effort.

Potential Commercial Applications: The technology developed in this project would be transferable to a wide range of commercial communications systems, both ground- and space-based.

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240 LeRC
89-1-14.05-1112 NAS3-25717
High-Instantaneous-Data-Rate, Burst-Signal Receiver
Q-Dot, Inc.
1069 Elkton Drive
Colorado Springs, CO 80907-3579
David E. Reed (719-590-1112)

An innovative technique will be investigated to acquire and digitize a packet of high-data-rate burst information. In this concept, a charge-coupled device (CCD) samples the received signal and detects the unique synchronization word. Upon unique-word detection, the timing of the data burst is determined, and the CCD device temporarily stores the burst-signal samples. These signal samples are then output at a slower rate compatible with a microprocessor, signal processor, or other low-data-rate demodulator. This device promises to greatly simplify the circuitry of time-division multiple access (TDMA) and other burst-data demodulators for governmental and commercial communications. It can be used in a TDMA receiver to achieve a low complexity with a low average data rate and very high instantaneous data rate, e.g., 1500 megabits per second.

Potential Commercial Applications: This effort could be the basis for applications in TDMA low-cost ground

terminals, high-capacity TDMA receivers, random-access packet receivers, and other burst signal systems. The approach allows very small, low-power, burst-modulation, multiple-access terminals, e.g., hand-held or single-board demodulators.

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* 241 LeRC
89-1-14.05-6000A NAS3-25867
High-Indium-Content, High-Electron-Mobility Transistors for RF Communications Devices
Spire Corporation
Patriots Park
Bedford, MA 01730
Patricia Sekula-Moise (617-275-6000)

In the field of satellite communications there exists an ongoing demand for high-performance transistors such as high-electron-mobility transistors (HEMTs). The focus of this project is the growth of high-indium-content pseudomorphic HEMTS by metalorganic chemical vapor deposition (MOCVD). By increasing the amount of indium present in the two-dimensional electron gas channel, significant gains may be realized in electron peak velocity, electron mobility, reduction of trap-related generation and recombination noise, and lower output conductance. These accomplishments will result ultimately in a superior high-speed device.

Potential Commercial Applications: High-indium-content pseudomorphic HEMTs should theoretically have higher transconductances than "standard" HEMTs, leading to their use in low-noise microwave amplifiers and oscillators in microwave control circuitry such as shifting and phase-shifting for antenna arrays.

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* 242 JPL
89-1-14.06-0755 NAS7-1076
Efficient, Low-Timing-Jitter Pulsed Lasers for Space Communications
Lightwave Electronics Corporation
1161 San Antonio Road
Mountain View, CA 94043
William M. Grossman (415-962-0755)

A laser-diode-pumped, solid-state laser that delivers high energy per pulse is needed for space communications. In this project, a full-power, laboratory version of such a laser will be designed, built, and tested. The laser will be tailored for use in data transmission by pulse position modulation. Over 0.1 millijoules per pulse at pulse repetition rates of up to 5 kilohertz will be produced; this will be the highest power available in a diode-pumped system at such a high repetition rate. Design options to allow even higher power will be considered. The laser will be diode-pumped in an end-pumped geometry for high efficiency and will use the emerging generation of high-brightness, 3-watt laser diodes. In addition to high pulsed power, the laser will have two more novel features that will make it ideal for pulse position modulation: intrinsically low timing jitter and timing delay independent of the interpulse period. The laser will be able to run with constant energy per pulse to higher repetition rates than any available solid-state laser.

Potential Commercial Applications: This pulsed laser will be used in the electronics industry for direct repair of integrated circuits where it will have superior power to present diode-pumped lasers.

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15: Materials Processing, Microgravity, and Commercial Applications in Space

* 243 MSFC
89-1-15.01-1772 NAS8-38468
Stabilized Electromagnetic Levitator
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
Robert Schiffman (312-272-1772)

This project will develop a novel, combined electromagnetic levitator-positioner and heater for commercial materials-processing in a non-contact environment. The stabilized electromagnetic levitator (SEL) is a three-axis system that will provide stable levitation and positioning of a wide variety of materials. The use of compact, broadband power amplifiers with an optimized coil design will allow efficient transmission of power to both the coils and the work-piece and permit independent control of heating, positioning, and spin. This design is well-suited to containerless studies of metal and metallic alloy systems, certain glasses and ceramics, and high-purity electronic and semiconductor materials. The SEL is uniquely suited for Earth-based and space-based processing of technologically or strategically significant materials. This is due to: efficient power utilization, optimization of conditions for positioning and heating, operations utilizing various atmospheres from vacuum to high pressure, and open access for process-control instrumentation.

Potential Commercial Applications: The results of designing, building, and characterizing a first-generation SEL will determine its potential applications for space-based and Earth-based manufacturing.

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244 MSFC
89-1-15.01-2043 NAS8-38450
Permanent Magnet Flight Furnace
Microgravity Systems, Inc.
4215 AL 72E
Brownsboro, AL 35741
Billy R. Aldrich (205-776-2043)

This project will result in a melt-growth flight furnace. A permanent magnet will provide a coaxial magnetic field along the growth axis to suppress convection flow in the melt, permitting production of single crystals with more uniform properties and better crystal quality. This project will develop the permanent-

magnet concept by selecting the materials and developing the preliminary design. A laboratory-prototype, permanent-magnet furnace will then be built and tested.

Potential Commercial Applications: This project could lead to utilization of the Earth-orbital environment for commercial production of materials. In addition, the size and design of this furnace system could provide a means to perform rapid quench or casting experiments using the KC-135 low-gravity simulator or sounding rockets.

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* **245** LeRC
89-1-15.02-1322A NAS3-25815
Combustion Diagnostics for Microgravity Research Using Near-Infrared Diode Lasers
Southwest Sciences, Inc.
1570 Pacheco Street #E-11
Santa Fe, NM 87501
Joel A. Silver (505-984-1322)

An improved method for measuring species concentrations and temperature will be developed for micro-gravity combustion research. The method will utilize inexpensive, room-temperature, laser diodes to measure absorption by important species in the fuel, oxidizer, and combustion products at near-infrared wavelengths. Combining these lasers with high-frequency detection techniques should result in a non-intrusive instrument with high sensitivity, wide dynamic range, and extremely fast-response time that is also useful for measurement of gas temperature in combustion flows. In comparison with other optically-based methods for measuring combustion species concentrations, the approach taken in this project uses exceptionally reliable and inexpensive laser sources that can readily be combined with fiber optics for multi-point monitoring. The feasibility of the technique will be demonstrated in Phase I by measurements in a room-temperature absorption cell and in the post-flame gases of a methane-air flame.

Potential Commercial Applications: Commercial applications may be expected in combustion process monitoring and control, gas monitoring in industrial chemical processes, pollutant and toxic gas sensing, and measurement of trace atmospheric species.

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246 LeRC
89-1-15.02-2299 NAS3-25813
Space-Qualified Laser for Microgravity Experiments
Schwartz Electro-Optics, Inc.
45 Winthrop Street
Concord, MA 01742
Peter F. Moulton (508-371-2299)

The project will develop an all-solid-state laser for spectroscopic analysis of reactive mixtures, a critical need for space-based combustion experiments. The approach used has the distinct advantage of being based on Ti:sapphire, a tunable laser material already under development for space-based lidar systems. The project will produce the first, space-qualifiable, tunable laser for visible to ultraviolet laser spectroscopy.

Potential Commercial Applications: This laser system would provide a source of tuneable infrared-to-ultraviolet light useful for basic spectroscopy, combustion diagnostics, and laser photochemistry.

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247 LeRC
89-1-15.02-5800 NAS3-25874
Novel, In Situ Technique to Visualize Convection on Solid-Liquid Interfaces
Brimrose Corporation of America
5020 Campbell Boulevard, Bldg 1
Baltimore, MD 21236
S. B. Trivedi (301-529-5800)

This project deals with the real-time effects of gravity-driven convection on solid-liquid interfaces during the crystal growth from melt. It makes use of a novel technique, based on the principles of infrared imaging, to visualize in situ the solid-liquid interface. It uses differences in emissivity to obtain demarcation between solid and liquid. At the same time, it also works in radiographic mode, depending upon the infrared transmission range of the material in question. The model material for these experiments is NaCl, chosen because of its wide IR-transmission range (0.2 microns - 26 microns) and well-understood physico-chemical properties. The infrared imaging of the solidification process will be carried out in the range of 3-5 microns. This technique is non-intrusive and non-destructive in nature, permits safe use without requiring any special precaution, and is amenable to both ground- and space-based experiments.

Potential Commercial Applications: Improved understanding of the effect of gravity-driven convection on the solid-liquid interface will help grow high quality crystals for various applications.

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248 LaRC
89-1-15.03-3800 NAS1-19029
Numerical Modeling of Particle Formation and Growth During Chemical Vapor Deposition
Creare, Inc.
P.O. Box 71
Hanover, NH 03755
Thomas J. Jasinski (603-643-3800)

Processing in the microgravity environment of space has the potential to improve the quality of thin films grown by chemical vapor deposition (CVD). Particle formation and growth in the precursor gas mixture is an especially important phenomenon in CVD due to its usually detrimental impact on film quality. This project will develop numerical modeling tools to predict nucleation and subsequent growth of particles during CVD. The effort is based on a computational fluid-dynamics-computer program called FLUENT that simulates many phenomena of interest to CVD. Phase I consists of implementing models for nucleation and growth in

order to demonstrate that FLUENT is a suitable framework for general-purpose modeling. Verification will be provided by comparison of results with previous work from the literature. If results are favorable, the models will be generalized during Phase II, yielding software for use by NASA scientists.

Potential Commercial Applications: Technology areas that could benefit from improved modeling of particulate formation include: CVD of thin films for electronics and optics; combustion with sooty flames; mitigating the fouling in heat exchangers; and formation of preforms for optical fibers using modified CVD.

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*** 249** MSFC
89-1-15.05-3779 NAS8-38455
Automatic Fault-Detection and Failure-Prediction for Spacecraft Systems
Technology Integration & Development Group
One Progress Road
Billerica, MA 01821
Nathan B. Higbie (508-667-3779)

An integrated, fault-detection and failure-prediction system for spacecraft mechanical, electrical, and structural systems will be developed. The approach combines pattern-recognition and fault-detection techniques that the firm developed for Navy helicopter gearboxes, with new research in failure prediction and machine learning. An advantage is that pattern recognition does not require a time-history data base, minimizing onboard memory requirements. The approach also has the benefit of a low false-alarm rate. The project objective is to demonstrate a hardware and software system by the end of Phase II.

Potential Commercial Applications: An integrated monitoring system for structures and for electrical and rotating machinery has considerable commercial potential. The system should be attractive to manufacturing and process industries where monitoring is only used at a low level.

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Appendix A: Description of the SBIR Program

Small Business Innovation Research

The Small Business Innovation Research (SBIR) program was instituted in 1982 by Public Law 97-219 and re-authorized through Fiscal Year 1993 by the enactment of Public Law 99-443 in 1986. Implementation of the program follows policy directives issued by the Small Business Administration (SBA). Eligibility is limited to U.S.-owned companies operating in the U.S. having fewer than 500 employees at the time a contract is awarded.

Purposes

The purposes of the Small Business Innovation Research program include stimulating U.S. technological innovation in the private sector, strengthening the role of small businesses in meeting Federal research and development needs, increasing the commercial application of Federally supported research results, and fostering and encouraging participation by minority and disadvantaged persons in technological innovation. Achievement of these purposes is accomplished through actions taken by the agency to meet its own particular R&D needs within the program framework established bylaws and the SBA policy directive guidelines.

SBIR Program Phases

As specified by the enabling legislation, SBIR is a three-phase R&D program. For Phase I, the objectives are to establish the feasibility and merit of an innovative scientific or technical concept proposed by a small business. Firms respond to a need or opportunity delineated by an agency in its annual Program Solicitation. Contracts for Phase I are awarded through a competitive selection process based on the evaluation of Phase I proposals submitted in response to Solicitation.

Phase II of SBIR is the principal research and development effort. Its purpose is the further development of the proposed ideas to meet the particular program needs. Only Phase I contractors may submit proposals to continue their Phase I research into Phase II. The selection of Phase II awards considers the scientific and technical merit and feasibility evidenced by the first phase, the expected value of the research to the agency, and the competence of the firm to conduct Phase II. In addition, for Phase II proposals considered to have essentially equivalent scientific merit and feasibility, special consideration is given to those that include valid non-Federal funding commitments for Phase III activities.

In Phase III, a small business can pursue commercial applications of the results of its SBIR-funded research. Phase III for commercial purposes is strongly encouraged by NASA as a major SBIR objective. Phase III may also take the form of follow-on R&D or production contracts with NASA or other Federal agencies for products and processes intended for use by the United States Government; however, such Phase III activities cannot be supported by the SBIR program funding set-aside.

Phase I and II Funding

NASA funding for SBIR projects is in keeping with guidelines for the SBIR program issued by the Small Business Administration. Phase I contracts are generally limited to six months in duration and $50,000, while contracts for Phase II are normally limited to two years' duration

and funding of not more than $500,000. NASA may make justifiable exceptions.

Proposal Evaluation and Award Selection

Evaluations of both Phase I and II proposals follow SBA policy guidelines and include technical merit and innovativeness, NASA R&D needs and priorities, program balance, and company capabilities. There are no quotas for specific technical areas. For Phase II, the Phase I results are a major factor and unlike Phase I, cost is an important consideration. And as noted above, for Phase II proposals of essentially equivalent merit, special consideration is given to those which include valid non-federal capital commitments for Phase III activities, particularly for pursuing commercial applications. Evaluators include NASA technical staff members at the Field Centers responsible for the Subtopics and the NASA Headquarters program officials. NASA, at its discretion, may also use outside evaluators.

Program History

Initiated in 1983, the NASA SBIR program has been supporting innovative R&D projects of interest to the agency and the aerospace community with funds set aside from the agency's research and development budget. As required by law, funding is 1.25 percent of NASA's annual budget for R&D contracting. For Fiscal Year 1989, $53 millions was provided to the NASA SBIR program. Including the amounts set aside for FY 1990 and 1991, the NASA SBIR program funding for all years of the program to date amounts to more than $350 millions for 1,513 Phase I and 632 Phase II awards. Since the NASA budget supports, in large part, the accomplishment of dedicated mission and R&D goals and has limited flexibility in the optional use of these specifically budgeted funds, the SBIR program constitutes a significant portion of the agency's discretionary research effort.

Small businesses have responded vigorously to the opportunities presented by the SBIR program. The number of Phase I proposals grew from 977 in 1983 to 2,148 in 1990. The number of Phase I awards selected has been limited each year not by the number of acceptable proposals but by the funds available and the desire that at least half of the Phase I projects proceed into Phase II. Awards have been made to 762 firms in 42 states, the District of Columbia and Puerto Rico. Approximately 17 percent of the firms submitting proposals have received Phase I awards, and about 48 percent of those firms have received Phase II continuations.

Appendix B: 1989 Topics and Subtopics

01 Aeronautical Propulsion and Power

- 01.01 Internal Fluid Mechanics for Aeronautical Propulsion Systems
- 01.02 Aeronautical Propulsion System Components
- 01.03 Aeronautical Propulsion System Instrumentation, Sensors and Controls
- 01.04 Novel Propulsion Concepts

02 Aerodynamics and Acoustics

- 02.01 Computational Fluid Dynamics
- 02.02 Experimental Fluid Dynamics
- 02.03 Theoretical Dynamics and Viscous Flows
- 02.04 Hypersonic Aerothermodynamics
- 02.05 Rarefied Gas Dynamics
- 02.06 Configurational Aerodynamics Including Vortices
- 02.07 Rotor Aerodynamics and Dynamics
- 02.08 Wind Tunnel Instrumentation
- 02.09 Aircraft Noise Reduction
- 02.10 Aeronautical Propulsion Noise Reduction

03 Aircraft Systems, Subsystems, and Operations

- 03.01 Aircraft Ice Protection Systems
- 03.02 Aircraft Flight Environment
- 03.03 Control Concepts for Fixed Wing Aircraft
- 03.04 Fully Automatic Guidance for Rotorcraft
- 03.05 Aircraft Flight Testing Techniques
- 03.06 Flight Research Sensors and Instrumentation
- 03.07 Hypersonic Flight Systems Technology
- 03.08 Very-High Altitude Aircraft Technology
- 03.09 Aeronautical Human Factors and Flight Management Systems
- 03.10 Computer-Aided Development, Testing, and Verification of Flight Critical Systems

04 Materials and Structures

- 04.01 Structural Composite Materials for Propulsion Systems
- 04.02 High Temperature Structural Composites
- 04.03 Composite Materials for Aerostructure and Space Applications
- 04.04 Advanced Alloys, Intermetallics and Metal Matrix Processes
- 04.05 Computational Structural Methods
- 04.06 Non-Destructive Evaluation to Characterize Material Properties
- 04.07 Bond Strength of Thermal Sprayed Coatings
- 04.08 Space Environmental Effects and Surface Degradation
- 04.09 Light Alloy Metallics for Airframe Structures
- 04.10 Welding Technology
- 04.11 Special-Purpose Materials for Space Flight Applications
- 04.12 Conductive Coating Systems for Scanning Electron Microscope Imaging
- 04.13 Spacecraft Structures and Mechanisms
- 04.14 Active Structural Elements for Space Applications
- 04.15 Materials for Space Transportation System and Space Station
- 04.16 High Temperature Superconducting Materials Fabrication and Characterization
- 04.17 High Temperature Superconductors for Aerospace Propulsion, Power, and Communications
- 04.18 Lunar Materials Utilization

05 Teleoperators and Robotics

- 05.01 Telerobotic Systems Technology
- 05.02 Telerobotic and Biomechanical System Software Development
- 05.03 Telerobotic Electro/mechanical Systems
- 05.04 Robotic Adaptive Grasping Systems
- 05.05 Artificial Intelligence for Space Station Applications
- 05.06 Teleoperation and Robotics
- 05.07 Space Mechanisms
- 05.08 Serpentine Robotic Arm
- 05.09 Mission Experiment Support Telerobotics

06 Computer Sciences and Applications

- 06.01 Engineering Computer Science
- 06.02 Advanced Software Development and Maintenance
- 06.03 Reliable Software Development
- 06.04 Knowledge-Based Systems Technologies for Aerospace Applications
- 06.05 Software Systems for Mission Planning and Flight Control
- 06.06 Computer Sciences Advances in Computational Physics
- 06.07 Large Multiprocessor Database Technology

07 Information Systems and Data Handling

- 07.01 Focal-Plane Image Processing
- 07.02 Image Data Compression and Analysis
- 07.03 Statistics of Spatial Patterns and Spatial Interaction Processes
- 07.04 Spatial Data Management and Geographic Information System (GIS)
- 07.05 Signal and Information Processing
- 07.06 Information Processing Technology and Integrated Data Systems
- 07.07 Scheduling and Automation Technology for Unmanned Spacecraft Operations

07.08 Heterogeneous Distributed Database Management
07.09 Spacecraft On-Board Information Extraction

08 Instrumentation and Sensors

08.01 Instruments for Sensing Electromagnetic Radiation
08.02 Earth Atmosphere Sensing from Low Earth Orbit
08.03 Low-Cost High Resolution Airborne Remote Sensing Instrumentation for Earth Sciences
08.04 Sensors for Aerosol and Cloud Studies
08.05 Polarized Laser Imaging of the Earth's Surface
08.06 Earth Atmospheric LIDAR Remote Sensing
08.07 Tunable Solid State Lasers, Detectors and LIDAR Subsystems
08.08 Coherent Laser Radar
08.09 Earth Observing Sensor Development for Geostationary Orbit
08.10 Flight Instrument Technology for Exobiology
08.11 Instrumentation for Planetary Atmospheric Sciences
08.12 Infrared Technology for Astronomical Applications
08.13 Detectors and Detector Arrays
08.14 Low-Cost Calibrators for Spaceborne Synthetic Aperture Radar
08.15 Earth-Based and Planetary Photometry Instrumentation
08.16 Submillimeter Antennas, Radiometers and Spectrometers
08.17 Altimetry Technology
08.18 Optical Systems and Devices
08.19 Three-Dimensional Reflectometer
08.20 Spacecraft and Space Station Contamination Monitoring
08.21 Instruments for STS Operations
08.22 Cryogenic Fluid Instrumentation for Orbiting Spacecraft

09 Spacecraft Systems and Subsystems

09.01 Control of Large Space Structures
09.02 Guidance, Navigation and Control of Advanced Space Transportation Systems
09.03 Combined Attitude Control and Energy Storage
09.04 STS and Space Station Robotic Tracking Systems
09.05 Spacecraft Meteoroid/Debris Protection Systems
09.06 Technologies for Scientific Balloons
09.07 High Temperature Superconductor Applications for Space
09.08 Spacecraft Flight Dynamics
09.09 Space Station Crew Workstation Displays and Controls
09.10 Space Orbiter Wheel Brake Control System
09.11 Manned Spacecraft and Planetary Based Thermal Management Systems
09.12 Thermal Control for Unmanned Space Applications
09.13 Spacecraft Systems Thermal Analysis and Design
09.14 Compartment Venting

10 Space Power

10.01 Space Power System Technologies
10.02 High Energy Density and Long Life Batteries
10.03 Separator Material for Aerospace Ni-Cd Cells
10.04 Photovoltaic Laser Energy Converters
10.05 Electrical Power Control and Distribution Subsystems
10.06 Space Power Advanced Automation Systems Automation
10.07 Power Transmission Applications of High-Temperature Superconductors

11 Space Propulsion

11.01 Space Propulsion System Technologies
11.02 Liquid Engine Internal Flow Dynamics
11.03 Cryogenic Propellant Management for Spacecraft
11.04 Solid Rocket Motor Technology
11.05 High Power Level Electro-Mechanical Thrust Vector Control
11.06 Contamination from Bi-Propellant Rocket Engines Exhaust Products

12 Human Habitability and Biology in Space

12.01 Medical Sciences for Manned Space Programs
12.02 Environmental Control and Life Support Systems for Space Station
12.03 Regenerative Life Support: Air, Water and Waste Management
12.04 Bioregenerative Food Production
12.05 Human Factors for Space Crews
12.06 Intravehicular Systems for Space Crews
12.07 Extravehicular Activity (EVA)
12.08 Biomedical and Environmental Hygiene Support for Manned Space Programs
12.09 Concepts and Components for Sterilization of On Board Water Systems
12.10 Physio-Chemical Life Support Systems
12.11 Life Sciences Spaceflight Hardware Development
12.12 Biological Sciences Operations
12.13 Parametric Nuclear Fragmentation Model
12.14 Anatomical Image Analysis Techniques

13 Quality Assurance, Safety, and Check-out for Ground and Space Operations

- 13.01 Ground Operations Instrumentation
- 13.02 Improved Propellant Handling at Launch Sites
- 13.03 Launch and Ground Weather Forecasting and Situation Management
- 13.04 Fluid System Components
- 13.05 Shuttle Landing Facility Bird Control
- 13.06 Test Facility Instrumentation and Safety Devices
- 13.07 Quality Assurance of Very Large Scale Integrated Circuits

14 Satellite and Space Systems Communications

- 14.01 Communications for Manned Space Systems
- 14.02 Advanced Data Relay Satellite Systems
- 14.03 Millimeter Wave Deep Space Communications Systems
- 14.04 Spacecraft Transponder Electronics
- 14.05 Advanced Satellite Communications Systems
- 14.06 Optical Communications for Deep Space
- 14.07 Low-Cost Ka-Band Ground Terminals

15 Materials Processing, Microgravity, and Commercial Applications in Space

- 15.01 Materials Processing in Space
- 15.02 Microgravity Science, Technology and Engineering Experiments
- 15.03 Chemical Vapor Deposition Analysis and Modeling Tools
- 15.04 Commercial Opportunities in Space Power Generation, Propulsion and Related Technologies
- 15.05 Acoustic Signatures of Failure Modes in Stressed Spacecraft Components
- 15.06 Self-Healing Insulation for Space-Exposed Power Transmission Lines

Appendix C: Index of 1989 Phase I Projects By State

Appendix D: Index of Participating Companies

Aurora Associates
Santa Clara, CA 95054
149: Wideband, Acousto-Optic, Spectra Analyzer
151: Acousto-Optic Tunable Filter

Aurora Flight Sciences Corporation
Alexandria, VA 22312
041*: Propulsion System for a High-Altitude Research Platform

Automatix, Inc.
Billerica, MA 01821
061*: Macro- and Task-Level Programming of Arc Welding Robots for Aerospace Applications

Autometric, Inc.
Alexandria, VA 22312-2312
116: Improved Accessing of Digital Data Bases by Geographic Information Systems

Axiomatics Corp.
Cambridge, MA 02142
222*: Remote Moisture Sensor to Control Irrigation of Plants in Space

B&D Instruments and Avionics
Valley Center, KS 67147
038: Evaluation of PVDF Film as a Pressure Sensor

Barr Associates, Inc.
Westford, MA 01886
153*: Ion Beam Deposition of Large-Area, Low-Scattering Metal Coatings

Barrett Technology, Inc.
Cambridge, MA 02138-1105
085*: A Robot Wrist Using New Mechanism Technology Invented for Whole-Arm Manipulation

Begej Corporation
Littleton, CO 80127
086*: Glove Controller with Force and Tactile Feedback for Dexterous Robotic Hands

Bend Research, Inc.
Bend, OR 97701-8599
217: Membrane-Based, High-Pressure Gas-Dehydration Module

Bio-Imaging Research, Inc.
Lincolnshire, IL 60069
198*: Slit Digital Radiography for Analysis of Bond Defects in Rocket Motors

Biotronics Technologies, Inc.
Wauwatosa, WI 53226
224*: Fiber Fluorometry for On-Line Chemical Analysis of Nutrient Solutions

Boston Advanced Technologies, Inc.
Boston, MA 02215
220*: Chemical Sensor System for the Identification of Organic Compounds in Water

Brimrose Corporation of America
Baltimore, MD 21236
247: Novel In-Situ Technique to Visualize Convection on Solid-Liquid Interfaces

CFD Research Corporation
Huntsville, AL 35805
005: Rapid-Mix Concepts for Low-Emission Combustors in Gas Turbin Engines
060: A Mathematical Model To Investigate Undercutting and To Optimize Weld Quality

CPS Superconductor Corp.
Milford, MA 01757
076: Ultra-Rapid, Textured Growth of Yttrium-Barium-Cuprate Filaments for Composite HTSC Wire

CSA Engineering, Inc.
Palo Alto, CA 94306-4682
055: Advanced Finite-Elements for Structural Analysis

Cape Cod Research, Inc.
Buzzards Bay, MA 02532
063: Improved Electro-Rheological Fluids for Lubricant Viscosity Control

Carnegie Group, Inc.
Pittsburgh, PA 15222
087: An Expert Advisor for Failure Mode and Effects Analysis

Castle Technology Corp.
Lexington, MA 02173
077: Increasing Critical Current Densities in High-T_c Superconductors

Center for Remote Sensing
Mclean, VA 22102
146: Improved Antenna for Synthetic-Aperture Radar Calibrator

Charles River Analytics, Inc.
Cambridge, MA 02138
161*: A Neural-Net Approach to Space Vehicle Guidance

Chi Systems, Inc.
Spring House, PA 19477
211: Capturing Space Crew Representations of Control Systems with Multi-Dimensional Scaling

Colorado Research Development Corp.
Boulder, CO 80301
097*: Parallel, Multilevel, Adaptive Methods for Flows in Transition

Computer Algorithm Development
Austin, TX 78705
095: Active Detection and Tracking Sensor for Passive Targets

Construction Technology Laboratories
Skokie, IL 60077
079: Feasibility Study for Lunar Cement Production

Continuum
Santa Clara, CA 95051
125*: Diode-Pumped, Short-Pulse Laser Transmitter for Ranging and Altimetry

Continuum Dynamics, Inc.
Princeton, NJ 08543
028*: General Flow-Field Analysis Methods for Helicopter Rotor Aeroacoustics

Cordec Corporation
Lorton, VA 22079-0188
054: Microstructurally Toughened, Intermetallic Matrix Composites
066: New Fabrication Methods for Dimensionally Stable, Graphite-Magnesium Space Structures

Creare, Inc.
Hanover, NH 03755
174*: Magnetic Bearings for Miniature, High-Speed Turbomachines
178: Condenser Design for Alkali-Metal Thermoelectric Conversion Systems
248: Numerical Modeling of Particle Formation and Growth During Chemical Vapor Deposition

creare.x Inc.
Hanover, NH 03755
013*: Advanced Modeling of Combustion Systems

Dataflow Computer Corp.
Belmont, MA 02178
107: Program Mapping Strategies for Multiprocessor Computers

Deacon Research
Palo Alto, CA 94303
018*: Remote Measurement System for Arc-Jet Temperature and Density

Delta G Corporation
Sun Valley, CA 91352
007: High-Temperature, Hostile-Environment Instruments Manufactured by CVD

Demografx
Culver City, CA 90232
108*: Application of High-Performance Digital Video to Computer Storage

Dieseldyne Corporation
Morrow, OH 45152
040: An Advanced Heat Rejection System for an AVCD Engine in a High-Altitude Research Platform

Digital Signal Corporation
Springfield, VA 22151
080*: Wavelength-Diplexed, Fiber-Coupled, Coherent Laser Radar Measurement System

Dimension Technologies, Inc.
Rochester, NY 14607
110*: A High-Resolution Autostereoscopic Display

Dynamic Microsystems
Goleta, CA 93117
088: A VLSI Three-Dimensional Processor for Advanced Robotic Manipulation
089*: A Precise, Force-Controlled Robotic System

EIC Laboratories, Inc.
Norwood, MA 02062
142: Efficient, Far-Infrared, Inductive Mesh Filters by Photoelectrochemical Etching
154*: Photoetched Echelle Gratings in Silicon
191: Robust High-T_c Ribbon for Power Transmission

EMEC Consultants
Export, PA 15632
078*: Production of Oxygen by Electrolysis of Lunar Soil in Molten Salt

ENSCO, Inc.
Springfield, VA 22151-2388
230*: Meteorological Monitoring System

Eastern Analytical, Inc.
College Park, MD 20742
204: Selective Enrichment of Stable Calcium Isotopes Using Laser Techniques

Eidetics International, Inc.
Torrance, CA 90505
023*: Aerodynamic Control of the F/A-18 Using Forebody Vortex Blowing
033: An Improved Methodology to Assess Departure Susceptibility Versus Agility

Electro-Optics Technology, Inc.
Fremont, CA 94538
137*: Multiple-Diode-Pumped, Ho:Tm:YAG Planar Ring Laser

Electroformed Nickel, Inc.
Corona, CA 91720
194*: High-Temperature, Oxidation-Barrier Coatings for Refractory Metals

ElectroImpact, Inc.
Seattle, WA 98105
031*: Eddy Current Repulsion De-Icing Strip

Energy Science Laboratories, Inc.
San Diego, CA 92121
185*: Composite Regenerator for Stirling Engine

Engineering Analysis, Inc.
Huntsville, AL 35801-5909
016*: Calculation of Surface Pressure Fluctuations Based on Time-Averaged, Turbulent Flow Computations
029: The Applications of Fractional Calculus to Noise Simulation

Epitaxx, Inc.
Princeton, NJ 08540
119: Visible Semiconductor Diode Lasers Grown by Hydride Vapor-Phase Epitaxy
123: A 128 X 128 Element, Indium-Gallium-Arsenide, IR Detector Array at 300 K

Ergo-Tech Systems, Inc.
Tujunga, CA 91042
201: Computer Simulation of Transient Operation of Small Bipropellant Engines

Exfluor Research Corporation
Austin, TX 78713-7807
062: New Perfluoropolyether Elastomers for Low- and High-Temperatures

FWG Associates, Inc.
Tullahoma, TN 37388
229: Instrumented-Rocket, Wind Profiler

Fare, Inc.
College Park, MD 20740
064*: A Composite Material Flywheel for Energy Storage

Femtometrics
Costa Mesa, CA 92627
226: A Real-Time, Particle Fall-Out Monitor

Florida Maxima Corporation
Winter Park, FL 32789
213: Performance of Groups in Extreme Environments: a Meta-Analytic Integration

Foa Engineering
North Bethesda, MD 20852
010: High-Efficiency Flow Induction

Food and Agrosystems, Inc.
Sunnyvale, CA 94088
210*: Methodologies for Processing Plant Materials into Acceptable Food on a Small Scale

Foster-Miller, Inc.
Waltham, MA 02154-1196
046: High-Temperature, Film-Based Polybenzoxazole/Polymide Microcomposite for Turbine Engines
049*: LaRC-TPI and Liquid-Crystal Polymer Blends
092*: Self-Contained, Deployable, Serpentine Truss for Prelaunch Access of Orbiter Payloads
164*: Novel Composites for Protection Against Orbital Debris
173: Heat Pump for Space Thermal Bus

G & C Systems, Inc.
San Juan Capistrano, CA 92675
044*: A Knowledge-Based Simulation Design, Development, and Coding Environment

Galaxy Microsystems, Inc.
Austin, TX 78759
238*: High-Speed, Digital Data Transmission

Galloway Research
San Jose, CA 95133
096: The LAFS Kernel File System

General Purpose Machines Laboratory
Irvine, CA 92715
120: A Neural-Network, Dynamic Sequencer for Distributed Mission Planning and Control

Geo Centers, Inc.
Newton Centre, MA 02159
223: Trace-Contaminant Vapor Monitors

Giner, Inc.
Waltham, MA 02254-9147
188: Nickel-Cadmium Battery Separator Design and Development

Gumbs Associates, Inc.
East Brunswick, NJ 08816
047: Soluble, Conducting-Polymer-Based Conductive Coatings

HITC Superconco, Inc.
Bordentown, PA 19007
167: High-Temperature Superconductor for Passive Magnetic Bearings

Hansen Research Associates
Eugene, OR 97403
019: Transport Properties in Non-Equilibrium Air Mixtures

High Technology Services, Inc.
Troy, NY 12180-8344
051*: Methods for Producing Fine-Particle, Thermoplastic Polyimide Sulfone Powder

Huntsville Sciences Corporation
Huntsville, AL 35805
180*: Finite-Element, and Adaptive-Grid Thermal Analyzer with Enhanced Graphics Capability

Hydrogen Consultants, Inc.
Littleton, CO 80125
186: Constant-Temperature Heat Storage in Metal Hydrides

ISM Technologies, Inc.
San Diego, CA 92131
065*: Miniature, Thin-Film Deposition System

ISX Corporation
Thousand Oaks, CA 91360
103*: Knowledge-Based Aerospace Program-Management Decision-Support System

Imatron, Inc.
South San Francisco, CA 94080
200: Assessment of Materials in Solid Rocket Motors by Real-Time CT

Information & Control Systems, Inc.
Hampton, VA 23666
026: A High-Temperature, Directional, Spectral Emissivity Measurement System

Infrared Fiber Systems, Inc.
Silver Spring, MD 20904
145*: Fiber Arrays for Low-Background Infrared Astronomy

Innovative Dynamics
Ithaca, NY 14850-1296
036: Low-Cost, Angle-of-Attack Sensor for Subsonic Aircraft
057*: Aircraft Health Monitoring System

Integrated Systems, Inc.
Santa Clara, CA 95054-1215
159: Control Structure Interaction: Optimization-Based Design Tools

Intelligent Automation, Inc.
Rockville, MD 20850
084: Telerobot Control Interface Based on Constraints

Interdisciplinary Science Applications
Rockville, MD 20852
127: A Stochastic Rain Model and Its Application in Rain-Rate Estimation

Interferometrics, Inc.
Vienna, VA 22182
150*: Dual K- and C-Band Transponder for Satellite Altimetric Calibration

Intersonics, Inc.
Northbrook, IL 60062
243*: Stabilized Electromagnetic Levitator

Iomed, Inc.
Salt Lake City, UT 84108
203: Transdermal Drug Delivery System for Application in Space Flight

Iowa Thin Film Technologies, Inc.
Ames, IA 50010
183*: Flexible, Lightweight, Amorphous-Silicon Solar Cells Tuned for AMO Spectrum

Irvine Sensors Corporation
Costa Mesa, CA 92626
099*: Three-Dimensional, Solid-State, Multi-Port Memory System
138: Space-Sensor, Common-Module Electronics

Johnson Aeronautics
Palo Alto, CA 94302
025: General Time-Domain Unsteady Aerodynamics of Rotors

KMS Fusion, Inc.
Ann Arbor, MI 48106-1567
090*: Global-Local Environment Telerobotic Simulator

Kestrel Development Corporation
Palo Alto, CA 94304
102*: Semi-Automatic Data Structure Selection

Light Age, Inc.
Warren, NJ 07060
132: Single, Longitudinal-Mode, Alexandrite Lidar Transmitter

Lightwave Electronics Corporation
Mountain View, CA 94043
242*: Efficient, Low-Timing-Jitter Pulsed Lasers for Space Communications

Lynntech, Inc.
Bryan, TX 77803
208*: Solid-Polymer, Electrolyte-Based Electrolyzers for Water Reclamation Post-Treatment

MIMD Systems, Inc.
Belmont, CA 94002
111*: A Distributed, Object-Oriented, Data Facility for Local-Memory, Parallel Computers

MOCO, Inc.
Scituate, MA 02055-0974
212*: Optimal Workspace Design

Management Project Marketing Consultants
Anaheim, CA 92807-3919
006: Influence of Tooth-Profile Modification on the Lubrication of Involute Gearing

Materials and Electrochemical Research
Tucson, AZ 85706
045: A Coated, Titanium Diboride, Whisker-Toughened, Silicon-Carbide Matrix Composite
069*: A Whisker-Reinforced, High-Temperature Structural Insulation

Metrolaser
Irvine, CA 92714-6428
017: A Holographic Interferometer Spectrometer for Hypersonic Flow

Micon Engineering
College Station, TX 77845
190*: Intelligent Protection System for Space Power Applications

Microcosm, Inc.
Torrance, CA 90505
168: Spacecraft Attitude Determination Using AI and Attitude Measurement Information Theory

Microgravity Systems, Inc.
Brownsboro, AL 35741
244: Permanent Magnet Flight Furnace

Microwave Monolithics, Inc.
Simi Valley, CA 93065
109: Advanced Optical Head Technology
236*: Monolithic, Gallium-Arsenide, UHF-IF, Switch Matrix for Space Station Applications
239*: Advanced Monolithic Gallium Arsenide Receiver Front-End for Spacecraft Transponders

Millitech Corporation
South Deerfield, MA 01373
139*: A Broadband, Multichannel, Precipitation Sensor

Moller International, Inc.
Davis, CA 95616
004*: Evaluation of PS200 Coating as a Thermal Barrier in an Air-Cooled Rotary Engine

Nektonics, Inc.
Cambridge, MA 02139
015: Transition tc Turbulence in Complex Aerodynamic Flows

Neocera Associates, Inc.
New Brunswick, NJ 08901
075*: Microwave-Compatible, High-T_c Superconducting Films on Sapphire Substrates

New Horizons Diagnostics
Columbia, MD 21045
219*: Device for Sample Collection and Rapid Immunological Identification of Biological Specimens

Nielsen Engineering & Research, Inc.
Mountain View, CA 94043-2287
021: A Model for Shock Turbulence Interaction

Nonvolatile Electronics, Inc.
Plymouth, MN 55441
122*: Ultra-Dense Magneto-Resistive Mass Memory

Numedioc
Bryn Mawr, PA 19010
225: Anatomical Image Analysis Techniques

Odyssey Research Associates, Inc.
Ithaca, NY 14850-1313
100: Formal Verification of C with Unix

Ophir Corporation
Lakewood, CO 80227
228*: A Novel Laser System for Forecasting and Mitigating Lightning Strikes

Optivision, Inc.
Palo Alto, CA 94304
112*: A Programmable, Image-Data Compression Subsystem for Workstations
114*: A Hybrid Simulation System for Image Data Compression

Optron Systems, Inc.
Bedford, MA 01730
143: Low-Cost, Imaging Electron-Multiplier Device
169: Low-Voltage, Thin-Film Electroluminescent Phosphor
235: An Electro-Optic Modulator for Laser Wavefront Correction and Positioning in Space

PDA Engineering
Costa Mesa, CA 92626
199: Physically Based Failure Criteria for Carbon-Phenolic Materials

Panametrics, Inc.
Waltham, MA 02254
158: Cryogenic, Ultrasonic, Mass-Flow Meter and Quality Meter

Phonon Corporation
Simsbury, CT 06070
237: Surface-Acoustic-Wave, Spectral Limiter for Narrow-Band Interference Suppression

Photometrics Limited
Tucson, AZ 85706-5006
144*: Backside-Illuminated, Large-Format, Charge-Coupled Devices and Mosaics
215*: Charge-Coupled Device Sensors for Electronic Still Photography

Photon Research Associates, Inc.
San Diego, CA 92121
083*: Integrated Ergonomic System Software Development

Photon Research Associates, Inc.
Cambridge, MA 02138
129: Multispectral, Remote Sensing Using SPRITE Technology

Photonic Systems, Inc.
Melbourne, FL 32901-2625
118*: Wideband, Multi-Channel, Acousto-Optic Spectrometer for Radio Astronomy Applications

Physical Optics Corporation
Torrance, CA 90501
163*: Dynamic, Coherently Coupled, Holographic Optical Elements Using Liquid Crystals

Physical Sciences, Inc.
Andover, MA 01810
003: Reaction Mechanics and Kinetic Rates for Soot Formation
008*: Laser-Induced Fluorescence Measurements of Velocity in Supersonic Reacting Flowfields
020*: High-Velocity Gas-Surface Accommodation

Program Development Corp. of Scarsdale
White Plains, NY 10601
002*: Grid-Generation Code with Automatic Zoning

Q-Dot, Inc.
Colorado Springs, CO 80907-3579
240: High-Instantaneous-Data-Rate, Burst-Signal Receiver

Quanta, Inc.
Smyrna, GA 30080
171: Universal, Bilateral, Robotic Controller

REI Systems
McLean, VA 22102-0183
121*: A Distributed, Object-Type Management System for Heterogeneous Environments

Radiation Monitoring Devices, Inc.
Watertown, MA 02172
073*: High-Field, High-T_c Superconducting Magnets
202*: Solid-State Neutron Dosimeter for Space Applications

Refractory Composites, Inc.
Whittier, CA 90606
039: Ceramic-Matrix-Composite for Hypersonic Engine Structures

Remtech, Inc.
Huntsville, AL 35805
022: Coupling of Unsteady Fluid Dynamics and Structures in Low-Density, High-Speed Flows
181: Integrated, CAD, Venting Analysis Package

Resource Technologies Group, Inc.
Morgantown, WV 26505-6751
207*: Thin Membrane Sensors

Ressler Associates, Inc.
Laurel, MD 20707
131: An Airborne, Laser-Depolarization, Imaging Sensor for Terrestrial Measurements

Ribbon Technology Corporation
Gahanna, OH 43230
053: Rapidly Solidified, Narrow, Titanium-Aluminide Strip
059: Process Control for Melt-Overflow, Rapid Solidification Technology

Rocky Research
Boulder City, NV 89005
172*: High-Density, Chemical-Thermal Storage System for Low Gravity Environments
177: High-Lift, Heat-Actuated, Solid-Vapor Heat Pump for Simultaneous Refrigeration and Water Heating

SCS Telecom, Inc.
Port Washington, NY 11050
162: Novel Direction-Finding for Robotic Tracking in the Space Station
234: Power- and Bandwidth-Efficient Digital Communications

Sarcos Research Corporation
Salt Lake City, UT 84111
082*: High-Performance, Multi-Axis Strain Sensing
216*: Using Robots in Testing NASA EVA Space Suits

Satcon Technology Corporation
Cambridge, MA 02139-4507
067*: Magnetostrictive Active-Member Control of Space Structures
068: Direct Measurement of Bolt Tension Utilizing Magnetostriction
182*: Integrated Power and Attitude-Control System for the Space Station

Schmidt Instruments, Inc.
Houston, TX 77005
128: Very-Large-Scale-Integration Time-Interval Units
156: Time-of-Flight Mass Spectrometry Instrument for Monitoring Contaminants in Space

Schmitt Technology Associates
New Haven, CT 06511
152: Gas-Jet Deposition of Optical Thin-Films for Extreme Ultra-Violet and Soft X-Ray Applications

Schwartz Electro-Optics, Inc.
Orlando, FL 32804
130*: Novel, Cobalt-Doped, Magnesium-Fluoride Lidar Aerosol Profiler

Schwartz Electro-Optics, Inc.
Concord, MA 01742
134*: Lasers Optimized for Pumping Titanium-Alumina Lasers
246: Space-Qualified Laser for Microgravity Experiments

Science & Engineering Services, Inc.
Silver Spring, MD 20904
133*: Systems for Continuous Tuning and Single-Mode Operation of Solid-State Lasers

Science Research Laboratory, Inc.
Somerville, MA 02143
136: Compact, Lightweight, Expanding-Beam CO2 Laser Amplifiers for Spaceborne Applications

Scientific Research Associates, Inc.
Glastonbury, CT 06033
001*: Flow in Turbine Blade Passages
195*: An Eulerian-Lagrangian Analysis for Liquid Flows with Vapor Bubbles

Scientific Systems, Inc.
Woburn, MA 01801
034*: Real-Time Adaptive Identification and Prediction of Flutter

Search Technology, Inc.
Norcross, GA 30092
043*: Methods and Tools for Assessing Limits of System Intelligence

Seca, Inc.
Huntsville, AL 35805
196*: Heat Transfer in Rocket Engine Combustion Chambers and Regeneratively Cooled Nozzles

Sets Technology, Inc.
Mililani, HI 96789
147*: Multichannel Occultation Photometer
148: Atmospheric Opacity Monitor

Software Productivity Solutions, Inc.
Indialantic, FL 32903
098*: CASE Visualization System
104*: Passive Knowledge Acquisition System

Southwest Sciences, Inc.
Santa Fe, NM 87501
245*: Combustion Diagnostics for Microgravity Research Using Near-Infrared Diode Lasers

Space Instruments, Inc.
Encinitas, CA 92024
126: Cloud-Top Radiometer

Spaceborne, Inc.
La Canada, CA 91011
160: A High-Speed, Fault-Tolerant Microprocessor for Space Applications

Spatial Information Sciences, Inc.
Stennis Space Center, MS 34529
117: Raster and Vector Data Integration, Interactive Edit and Analysis

Speech Systems, Inc.
Tarzana, CA 91356
101: Site-Specific, Air-Traffic-Control Training Simulator with Speech Input and Output

Spire Corporation
Bedford, MA 01730
135*: Development of 780- and 792-Nanometer Diode-Laser Pumps for Solid-State Lasers
189*: Vertical, Multijunction, Photovoltaic Cells with Buried Silicide Interconnections
241*: High-Indium-Content, High-Electron-Mobility Transistors for RF Communications Devices

Star Enterprises, Inc.
Bloomington, IN 47402
221: Automated Food Delivery to Rodents in Space

Stirling Technology Company
Richland, WA 99352
175: A High-Efficiency, Low-Vibration, Long-Life, Stirling Cryogenic Pre-Cooler

Stoddard-Hamilton Aircraft, Inc.
Arlington, WA 98223
032*: Lightning Protection Technology for Smaller General Aviation Aircraft

Superconductor Technologies, Inc.
Santa Barbara, CA 93111-2310
072: In-Situ Thallium Films by Laser Ablation

Systems & Processes Engineering Corp.
Austin, TX 78721
056*: Digital, Optical Phase-Lock-Loop for Non-Destructive Evaluation

TNA Technologies, Inc.
Bozeman, MT 59715
155: Broadband Source for a Three-Dimensional Reflectometer

TPL, Inc.
Albuquerque, NM 87109
227: A Repair Coating for Cryogenic Transfer Lines

Technology Integration & Dev. Group
Billerica, MA 01821
249*: Automatic Fault-Detection and Failure-Prediction for Spacecraft Systems

Technology International, Inc.
Laplace, LA 70068
115: Application of Fractals to Smoothing over the Parameter Space

Teknowlogica, Inc.
Princeton Junction, NJ 08550
009: Non-Intrusive, Single-Point Pressure and Temperature Sensor for Aeronautical Propulsion Applications

Textile Technologies, Inc.
Hatboro, PA 19040
050: Multi-Angular Weaving for Composite Preforms

Thermacore, Inc.
Lancaster, PA 17601
176*: Sintered-Powder, Artery-Free Wicks for Low-Temperature Heat Pipes
179*: Composite Material Heat Pipes

Togai Infralogic, Inc.
Irvine, CA 92714
105*: Fuzzy-Clips Expert System

Tracer Technologies, Inc.
Somerville, MA 02145
166*: A Low-Thermal-Conductivity Connector

Transitions Research Corporation
Danbury, CT 06810
093: Tortuous-Path Robot Transport

Ultramet
Pacoima, CA 91331
052: CVD Chromium-Diboride Fibers for Metal-Matrix Composites

Umpqua Research Company
Myrtle Creek, OR 97457
205: A Reagentless Separator for Removal of Inorganic Carbon from Solution
209*: Electrochemical Water Recovery Process for Direct Removal of Impurities
218: Thermally Desorbable Toxin and Odor Control Cartridge

Unique Mobility, Inc.
Englewood, CO 80110
091*: Brushless Motor Robotic Actuator Optimization

Vexcel Corporation
Boulder, CO 80301-5703
113: HIRIS-Oriented Visualization Software System

Wilson Greatbatch Ltd.
Clarence, NY 14031
187: Rechargeable Lithium/Titanium-Disulfide Cells with Long Cycle-Life

Winzen International, Inc.
San Antonio, TX 78249
165*: Automated Seal-Flaw Detection

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NAS2: Ames Research Center

NAS2-13023	035*	89-1-03.05-7093
NAS2-13024	038	89-1-03.06-1223
NAS2-13125	025	89-1-02.07-3944
NAS2-13129	037	89-1-03.06-0655
NAS2-13130	044*	89-1-03.10-0753
NAS2-13131	040	89-1-03.08-3226B
NAS2-13132	034*	89-1-03.05-5355
NAS2-13155	023*	89-1-02.06-8228A
NAS2-13156	042	89-1-03.08-7121
NAS2-13157	024	89-1-02.07-3017A
NAS2-13158	041*	89-1-03.08-5694
NAS2-13159	213	89-1-12.05-9275
NAS2-13161	103*	89-1-06.04-8265
NAS2-13163	109	89-1-06.06-6642
NAS2-13164	108*	89-1-06.06-2985
NAS2-13165	107	89-1-06.06-2748A
NAS2-13166	142	89-1-08.12-9450
NAS2-13167	221	89-1-12.11-3309
NAS2-13168	210*	89-1-12.04-8450B
NAS2-13169	140*	89-1-08.10-7780
NAS2-13171	017	89-1-02.04-0688A
NAS2-13172	018*	89-1-02.04-1520
NAS2-13174	102*	89-1-06.04-6871
NAS2-13175	101	89-1-06.04-0885
NAS2-13176	011	89-1-02.01-1427
NAS2-13177	110*	89-1-06.06-7450

NAS3: Lewis Research Center

NAS3-25630	045	89-1-04.01-1980A
NAS3-25717	240	89-1-14.05-1112
NAS3-25813	246	89-1-15.02-2299
NAS3-25814	158	89-1-08.22-2719
NAS3-25815	245*	89-1-15.02-1322
NAS3-25824	048	89-1-04.02-0018
NAS3-25825	183*	89-1-10.01-3203
NAS3-25826	007	89-1-01.03-4888
NAS3-25828	009	89-1-01.03-9654A
NAS3-25829	030*	89-1-02.10-7070
NAS3-25830	192*	89-1-11.01-0321A
NAS3-25833	091*	89-1-05.07-2137
NAS3-25834	005	89-1-01.02-6576
NAS3-25835	001*	89-1-01.01-0333B
NAS3-25836	031*	89-1-03.01-2403
NAS3-25837	194*	89-1-11.01-4707
NAS3-25838	054	89-1-04.04-8044
NAS3-25839	003	89-1-01.01-9030A
NAS3-25840	008*	89-1-01.03-9030
NAS3-25867	241*	89-1-14.05-6000A
NAS3-25868	074*	89-1-04.17-2681
NAS3-25869	075*	89-1-04.17-2694
NAS3-25871	046	89-1-04.01-3200
NAS3-25872	053	89-1-04.04-5444A
NAS3-25873	004*	89-1-01.02-5086
NAS3-25874	247	89-1-15.02-5800
NAS3-25875	184*	89-1-10.01-4310
NAS3-25876	076	89-1-04.17-3422A
NAS3-25879	055	89-1-04.05-7351
NAS3-25880	002*	89-1-01.01-1732A
NAS3-25885	186	89-1-10.01-7972
NAS3-25886	052	89-1-04.04-0236
NAS3-25887	193*	89-1-11.01-4577
NAS3-25888	185*	89-1-10.01-4688
NAS3-25889	047	89-1-04.01-9049
NAS3-25941	010	89-1-01.04-2685
NAS3-25955	006	89-1-01.02-9888

Kennedy Space Center

092*	89-1-05.08-3200
093	89-1-05.08-8988
222*	89-1-12.12-6700
223	89-1-12.12-7070
224*	89-1-12.12-7653
225	89-1-12.14-5668A
226	89-1-13.01-6239
227	89-1-13.02-4256
228*	89-1-13.03-1512
230*	89-1-13.03-4122
231*	89-1-13.04-2888

Langley Research Center

013*	89-1-02.01-3800
014	89-1-02.02-0559
015	89-1-02.03-5750
020	89-1-02.04-4007
021	89-1-02.04-9457
026	89-1-02.08-0371
027*	89-1-02.08-0655
028*	89-1-02.09-9282
032*	89-1-03.02-8533
033	89-1-03.03-8228A
036	89-1-03.06-0533
039	89-1-03.07-8061
043*	89-1-03.09-1457B
049*	89-1-04.03-3200
050	89-1-04.03-5325
051*	89-1-04.03-8072
056*	89-1-04.06-0318
057*	89-1-04.06-0533
059	89-1-04.09-5444
073*	89-1-04.17-1167
080*	89-1-05.01-9200
081	89-1-05.01-9355
096	89-1-06.01-2490
097*	89-1-06.01-8633
100	89-1-06.03-2020
112*	89-1-07.01-4429
119	89-1-07.06-1188
130*	89-1-08.04-1802
134*	89-1-08.07-2299
135*	89-1-08.07-6000A
159	89-1-09.01-1500
160	89-1-09.02-0126
161*	89-1-09.02-3474
189*	89-1-10.04-6000
248	89-1-15.03-3800

Lewis Research Center

001*	89-1-01.01-0333B
002*	89-1-01.01-1732A
003	89-1-01.01-9030A
004*	89-1-01.02-5086
005	89-1-01.02-6576
006	89-1-01.02-9888
007	89-1-01.03-4888
008*	89-1-01.03-9030
009	89-1-01.03-9654A
010	89-1-01.04-2685
030*	89-1-02.10-7070
031*	89-1-03.01-2403
045	89-1-04.01-1980A
046	89-1-04.01-3200
047	89-1-04.01-9049
048	89-1-04.02-0018
052	89-1-04.04-0236
053	89-1-04.04-5444A
054	89-1-04.04-8044
055	89-1-04.05-7351
074*	89-1-04.17-2681
075*	89-1-04.17-2694
076	89-1-04.17-3422A
091*	89-1-05.07-2137
158	89-1-08.22-2719
183*	89-1-10.01-3203
184*	89-1-10.01-4310
185*	89-1-10.01-4688
186	89-1-10.01-7972
192*	89-1-11.01-0321A
193*	89-1-11.01-4577
194*	89-1-11.01-4707
240	89-1-14.05-1112
241*	89-1-14.05-6000A
245*	89-1-15.02-1322A
246	89-1-15.02-2299
247	89-1-15.02-5800

Marshall Space Flight Center

012	89-1-02.01-3304
016*	89-1-02.03-9391
022	89-1-02.05-8581
029	89-1-02.09-9391
058*	89-1-04.08-6381
060	89-1-04.10-6576
061*	89-1-04.10-7900
077	89-1-04.17-5634
094*	89-1-05.09-5959A
095	89-1-05.09-6511
136	89-1-08.08-1122A
137*	89-1-08.08-4022
138	89-1-08.09-8211A
139*	89-1-08.09-8551
164*	89-1-09.05-3200
177	89-1-09.13-0851A
178	89-1-09.13-3800
179*	89-1-09.13-6551
180*	89-1-09.13-8122
181	89-1-09.14-8561
182*	89-1-10.01-0540
190*	89-1-10.06-8911
195*	89-1-11.02-0333
196*	89-1-11.02-2008
197*	89-1-11.03-8629C
198*	89-1-11.04-6425
199	89-1-11.04-8900A
200	89-1-11.04-9964
205	89-1-12.02-5201B
206	89-1-12.02-5615
207*	89-1-12.02-6706
220*	89-1-12.09-0966
229	89-1-13.03-1982
243*	89-1-15.01-1772
244	89-1-15.01-2043
249*	89-1-15.05-3779

Stennis Space Center

115	89-1-07.03-1127
116	89-1-07.04-4000
117	89-1-07.04-6685
129	89-1-08.03-1522

C-2

NAS5: Goddard Space Flight Center

NAS5-30807	084	89-1-05.03-40071
NAS5-30809	062	89-1-04.11-3812
NAS5-30840	121*	89-1-07.08-1745
NAS5-30841	155	89-1-08.19-5976
NAS5-30842	237	89-1-14.02-0211
NAS5-30843	188	89-1-10.03-7270
NAS5-30844	154*	89-1-08.18-9450
NAS5-30845	120	89-1-07.07-3327
NAS5-30846	126	89-1-08.02-7001
NAS5-30847	118*	89-1-07.05-8181
NAS5-30848	098*	89-1-06.02-3370
NAS5-30849	127	89-1-08.02-7518A
NAS5-30850	145*	89-1-08.13-9546
NAS5-30851	132	89-1-08.06-0600
NAS5-30852	167	89-1-09.07-9722
NAS5-30853	082*	89-1-05.03-0559B
NAS5-30854	174*	89-1-09.12-3800A
NAS5-30855	064*	89-1-04.11-7412
NAS5-30856	165*	89-1-09.06-7062
NAS5-30857	133*	89-1-08.06-4161
NAS5-30858	063	89-1-04.11-5911
NAS5-30859	238*	89-1-14.02-7606
NAS5-30860	175	89-1-09.12-4000
NAS5-30861	176*	89-1-09.12-6551
NAS5-30862	166*	89-1-09.07-6410
NAS5-30863	131	89-1-08.05-3232
NAS5-30864	128	89-1-08.02-9040
NAS5-30865	156	89-1-08.20-9040
NAS5-30866	143	89-1-08.13-3100
NAS5-30867	173	89-1-09.12-3200
NAS5-30868	125*	89-1-08.02-3240
NAS5-30869	113	89-1-07.02-0094
NAS5-30870	144*	89-1-08.13-8961
NAS5-30871	099*	89-1-06.02-8211
NAS5-30872	083*	89-1-05.03-1522
NAS5-30873	152	89-1-08.18-5130
NAS5-30874	168	89-1-09.08-9444
NAS5-30890	114*	89-1-07.02-4429

NAS7: Jet Propulsion Laboratory

NAS7-1074	090*	89-1-05.06-8500
NAS7-1075	124	89-1-08.01-2681
NAS7-1076	242*	89-1-14.06-0755
NAS7-1077	122*	89-1-07.09-8659
NAS7-1078	141*	89-1-08.11-5435
NAS7-1079	065*	89-1-04.12-2332
NAS7-1080	201	89-1-11.06-1759
NAS7-1081	187	89-1-10.02-6901
NAS7-1082	149	89-1-08.16-0827
NAS7-1083	233*	89-1-13.07-7780
NAS7-1084	146	89-1-08.14-0800
NAS7-1085	111*	89-1-06.07-7505
NAS7-1086	089*	89-1-05.06-3729A
NAS7-1087	123	89-1-08.01-1188
NAS7-1088	148	89-1-08.15-5262B
NAS7-1090	072	89-1-04.16-7646A
NAS7-1091	067*	89-1-04.14-0540
NAS7-1092	191	89-1-10.07-9450
NAS7-1093	151	89-1-08.18-0827
NAS7-1094	071	89-1-04.16-4995
NAS7-1095	153*	89-1-08.18-7513B
NAS7-1096	088	89-1-05.06-3729
NAS7-1097	150*	89-1-08.17-8500
NAS7-1098	239*	89-1-14.04-6642
NAS7-1106	147*	89-1-08.15-5262

NAS8: Marshall Space Flight Center

NAS8-38436	178	89-1-09.13-3800
NAS8-38437	179*	89-1-09.13-6551
NAS8-38438	195*	89-1-11.02-0333
NAS8-38439	206	89-1-12.02-5615
NAS8-38440	164*	89-1-09.05-3200
NAS8-38441	137*	89-1-08.08-4022
NAS8-38442	190*	89-1-10.06-8911
NAS8-38443	094*	89-1-05.09-5959A
NAS8-38444	199	89-1-11.04-8900A
NAS8-38445	200	89-1-11.04-9964
NAS8-38446	220*	89-1-12.09-0966
NAS8-38447	060	89-1-04.10-6576
NAS8-38448	061*	89-1-04.10-7900
NAS8-38449	197*	89-1-11.03-8629C
NAS8-38450	244	89-1-15.01-2043
NAS8-38451	138	89-1-08.09-8211A
NAS8-38452	029	89-1-02.09-9391
NAS8-38453	180*	89-1-09.13-8122
NAS8-38454	196*	89-1-11.02-2008
NAS8-38455	249*	89-1-15.05-3779
NAS8-38456	022	89-1-02.05-8581
NAS8-38457	181	89-1-09.14-8561
NAS8-38458	095	89-1-05.09-6511
NAS8-38459	198*	89-1-11.04-6425
NAS8-38460	205	89-1-12.02-5201B
NAS8-38461	182*	89-1-10.01-0540
NAS8-38462	136	89-1-08.08-1122A
NAS8-38463	058*	89-1-04.08-6381
NAS8-38464	077	89-1-04.17-5634
NAS8-38465	229	89-1-13.03-1982
NAS8-38466	016*	89-1-02.03-9391
NAS8-38467	139*	89-1-08.09-8551
NAS8-38468	243*	89-1-15.01-1772
NAS8-38469	177	89-1-09.13-0851A
NAS8-38470	207*	89-1-12.02-6706
NAS8-38471	012	89-1-02.01-3304

NAS9: Johnson Space Center

NAS9-18301	070	89-1-04.15-5301
NAS9-18302	232	89-1-13.06-9500
NAS9-18303	170	89-1-09.09-4995
NAS9-18304	157	89-1-08.21-8442
NAS9-18305	214*	89-1-12.06-8100
NAS9-18306	106	89-1-06.05-9896
NAS9-18307	085*	89-1-05.04-3909
NAS9-18308	086*	89-1-05.04-5042
NAS9-18309	217	89-1-12.07-4100A
NAS9-18310	087	89-1-05.05-6900
NAS9-18311	211	89-1-12.05-1400
NAS9-18312	079	89-1-04.18-7500
NAS9-18313	066	89-1-04.13-8044
NAS9-18314	204	89-1-12.01-7751I
NAS9-18315	078*	89-1-04.18-3260A
NAS9-18316	203	89-1-12.01-1191
NAS9-18317	208*	89-1-12.03-4131
NAS9-18318	069*	89-1-04.15-1980
NAS9-18319	236*	89-1-14.01-6642
NAS9-18320	212*	89-1-12.05-2040
NAS9-18321	219*	89-1-12.08-9357
NAS9-18322	235	89-1-14.01-3100
NAS9-18323	169	89-1-09.09-3100
NAS9-18324	215*	89-1-12.06-8961
NAS9-18325	163*	89-1-09.04-1416B
NAS9-18326	020*	89-1-02.04-9030
NAS9-18327	171	89-1-09.09-9511
NAS9-18328	202*	89-1-12.01-1167
NAS9-18329	172*	89-1-09.11-0851A
NAS9-18330	216*	89-1-12.07-0559A
NAS9-18331	068	89-1-04.15-0540
NAS9-18332	234	89-1-14.01-0760A
NAS9-18333	162	89-1-09.04-0760
NAS9-18334	104*	89-1-06.05-3370
NAS9-18335	105*	89-1-06.05-8522
NAS9-18336	209*	89-1-12.03-5201
NAS9-18337	218	89-1-12.08-5201

NAS10: Kennedy Space Center

NAS10-11650	225	89-1-12.14-5668A
NAS10-11651	226	89-1-13.01-6239
NAS10-11652	223	89-1-12.12-7070
NAS10-11653	231*	89-1-13.04-2888
NAS10-11654	227	89-1-13.02-4256
NAS10-11655	228*	89-1-13.03-1512
NAS10-11656	224*	89-1-12.12-7653
NAS10-11657	222*	89-1-12.12-6700
NAS10-11658	093	89-1-05.08-8988
NAS10-11659	092*	89-1-05.08-3200
NAS10-11660	230*	89-1-13.03-4122

NAS13: Stennis Space Center

NAS13-406	129	89-1-08.03-1522
NAS13-409	116	89-1-07.04-4000
NAS13-410	117	89-1-07.04-6685
NAS13-411	115	89-1-07.03-1127